Rapid endovascular bailout revascularization of the renal arteries with a steerable guiding sheath after endovascular abdominal aortic aneurysm repair

Ningzhi Gu, BSc,[a] Jeffery G. Grab, MD,[a,b] *and* Randy D. Moore, MD,[a,b] *Calgary, Alberta, Canada*

ABSTRACT

Advancements in endovascular therapy have made it increasingly available for patients with complex cases but not without complications. Unintentional coverage of the renal arteries is a rare occurrence during endovascular aortic aneurysm repair. Given the potentially devastating repercussions, it is important that surgeons understand the suitability and the risks and benefits of the available revascularization options. We have described two cases of unintentional renal coverage, with subsequent successful bailout via direct manipulation of the stent-graft with a steerable sheath. We also conducted a review of the reported data, discussed the breadth of management options and their technical aspects, and provided several distinct solutions. (J Vasc Surg Cases and Innovative Techniques 2021;7:572-6.)

Keywords: Endovascular aneurysm repair; Accidental coverage; Renal occlusion; Bailout; Chimney grafting; Parallel grafting; Steerable sheath

Renal dysfunction occurs in ∼3.3% of endovascular abdominal aortic aneurysm repairs (EVARs).[1] An important and dramatic cause is the unintentional coverage of the renal artery orifices during stent-graft deployment. Although rare, with a modern incidence of <1%,[2] the consequences are devastating, especially in the setting of bilateral coverage. We present two cases in which we have demonstrated that steerable guiding sheaths can be used to manipulate malpositioned aortic stent-grafts, enabling selective cannulation and the deployment of salvage stents in inadvertently covered renal arteries. The patients have provided written informed consent for the report of their case details and imaging studies.

CASE REPORT

Patient 1. Patient 1, a 76-year-old man, underwent elective EVAR for a fusiform infrarenal abdominal aortic aneurysm with expansion to 60 mm in the maximal axial diameter. Computed tomography angiography revealed a mildly calcific aortic neck that was 24.6 mm wide and 12.0 mm in length as measured from the slightly downward coursing left and right renal arteries to the proximal aneurysm sac.

Intraoperatively, the procedure went accordingly with placement of a bifurcated C3 Excluder and iliac limb devices (W. L. Gore and Associates, Inc, Flagstaff, Ariz) through bilateral percutaneous femoral access. The device was deployed immediately inferior to the left and right renal arteries. Completion angiography, after balloon dilation of the stent-graft, showed that the aneurysmal pathology had been excluded but the graft had migrated ∼10 mm distally (Fig 1, *A*). A proximal aortic neck extension cuff (W. L. Gore and Associates, Inc) was then deployed, with inadvertent coverage of both the left and the right renal ostia (Fig 1, *B*). An 8.5F Destino Twist sheath (Oscor Inc, Palm Harbor, Fla) with a 7F renal curved Destination guide sheath (Terumo Medical Canada Inc, Vaughan, Ontario, Canada) was rapidly placed to retract the fabric of the extension cuff inferiorly by flexing the Oscor sheath, providing enough clearance for cannulation of the renal arteries with a Glidewire (Terumo Medical Canada Inc; Fig 1, *C* and *D*) followed by placement of 7-mm Advanta V12 covered stents (Atrium Medical Corp, Merrimack, NH) bilaterally. The completion angiogram demonstrated excellent flow to both renal arteries (Fig 1, *E*). During follow-up, there was no evidence of renal dysfunction or residual endoleak.

Patient 2. Patient 2, a 78-year-old man with a rapidly enlarging (>0.5 cm within 6 months) 51-mm abdominal aortic aneurysm at maximal axial diameter underwent elective EVAR. Computed tomography angiography revealed an aortic neck that measured 21 mm in diameter and a renal artery to aortic sac neck length of 48 mm with slight reverse conicity. Both renal arteries had steep downward going trajectories, with the left renal artery lower by 9 mm.

A bifurcated C3 Excluder (W. L. Gore and Associates, Inc) was selected and deployed. Completion angiography revealed that the stent-graft was malpositioned over both renal ostia (Fig 2, *A*). A reverse curve SOS Omni catheter (AngioDynamics Canada Inc, Oakville, Ontario, Canada) and Glidewire (Terumo Medical Canada Inc) were used to cannulate the more superior

From the Cumming School of Medicine,[a] and Division of Vascular Surgery, Department of Surgery,[b] University of Calgary.

Author conflict of interest: none.

NG and JG contributed equally to this article and share co-first authorship.

Correspondence: Randy D. Moore, MD, Division of Vascular Surgery, Department of Surgery, University of Calgary, 3500 26 Avenue NE, Calgary, AB T1Y 6J4, Canada (e-mail: randyd.moore@albertahealthservices.ca).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2468-4287

https://doi.org/10.1016/j.jvscit.2021.04.015

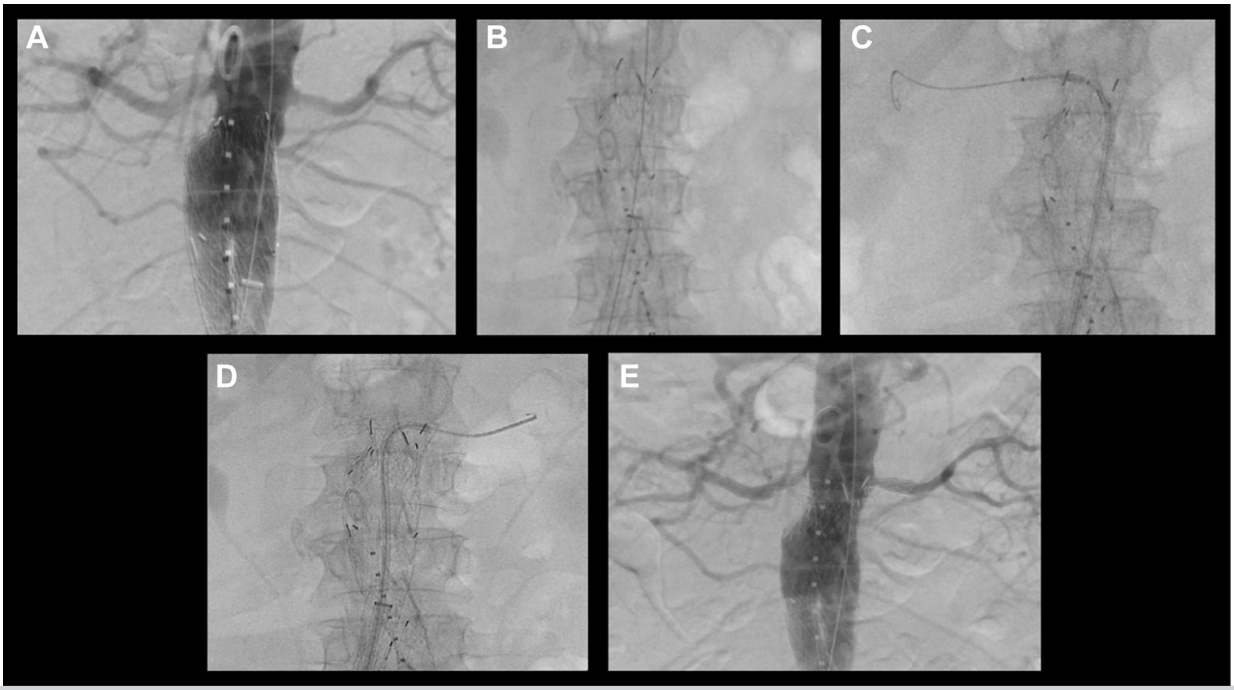

Fig 1. Fluoroscopic images obtained during endovascular abdominal aortic aneurysm repair (EVAR) for patient 1. **A,** The Gore C3 Excluder stent-graft was fully deployed with some unexpected distal migration and clear visualization of the renal arteries. Images showing a maldeployed Gore proximal extension cuff above the level of the renal arteries **(B)** with a steerable Oscor sheath used to purposefully retract the cuff fabric **(C)**. Access to the renal arteries was successfully obtained bilaterally with fabric retraction from the renal ostia (**C** and **D**). **E,** Completion angiogram showing bilateral parallel stents placed in each renal artery with excellent patency.

right renal artery, and an Advanta V12 7-mm covered stent (Atrium Medical Corp) was deployed into the vessel. The more inferior left renal artery had been entirely covered by the stent-graft fabric, rendering direct cannulation impossible (Fig 2, *B*). An 8.5F renal curved Destino Twist sheath (Oscor Inc) with a 7F renal curved Destination guide sheath (Terumo Medical Canada Inc) placed within provided a stiff system to catch the top of the fabric, and the Oscor sheath (Oscor Inc) was then flexed, folding it inferiorly (Fig 2, *C*). A noncompliant Coda balloon (Cook Medical, Bloomington, Ind) was advanced through the contralateral groin and placed just superior to the renal ostia and inflated to 2 atm, allowing a buddy Glidewire (Terumo Medical Canada Inc) to deflect off the balloon and into the defect made with the guiding sheath, cannulating the vessel (Fig 2, *D* and *E*). An Advanta V12 7-mm covered stent (Atrium Medical Corp) was then deployed in a parallel fashion to reestablish the flow. Completion angiography revealed excellent flow through this aortorenal reconstruction (Fig 2, *F*). The patient did well postoperatively with no loss of kidney function.

DISCUSSION

Although aortic stent-graft migration at deployment is a well-documented phenomenon, proximal migration is rare and thought to result from the sudden release of the elastic potential energy stored in the stiff wire or delivery device during deployment or fracture of the fixation components of the graft.[3,4] Technical errors, device defects, extensive calcification, and/or anatomic complexity could also be contributing factors.

Patients who have undergone urgent repair “off the instructions for use” with short necks have had an increased complication rate, including unintentional renal coverage.[5] We have limited our use of off the instructions for use endovascular applications to those patients deemed medically unfit and those at high risk of open repair, with either abdominal symptoms referable to the aorta (unable to wait 4 weeks for fenestrated repair) or anatomy not suitable to more complicated fenestrated or branched graft repair. In these patients with a neck length measuring 10 to 15 mm long, we will use standard endovascular techniques and attempt to precisely place the device adjacent to the renal arteries with intraoperative hypotension (systolic blood pressure <90 mm Hg) during deployment to minimize the “windsock” effect, with or without subsequent Palmaz stent placement in the aortic neck or endoanchors, depending on the findings from the completion angiogram (type Ia endoleak). For patients requiring urgent endovascular repair with a neck length of 5 to 10 mm, we will plan to use a Palmaz stent or endoanchors, or both, to ensure proximal fixation. We do not routinely offer endovascular repair for patients with a neck length <5 mm at our institution. In our experience, the use of parallel graft or chimney techniques are not

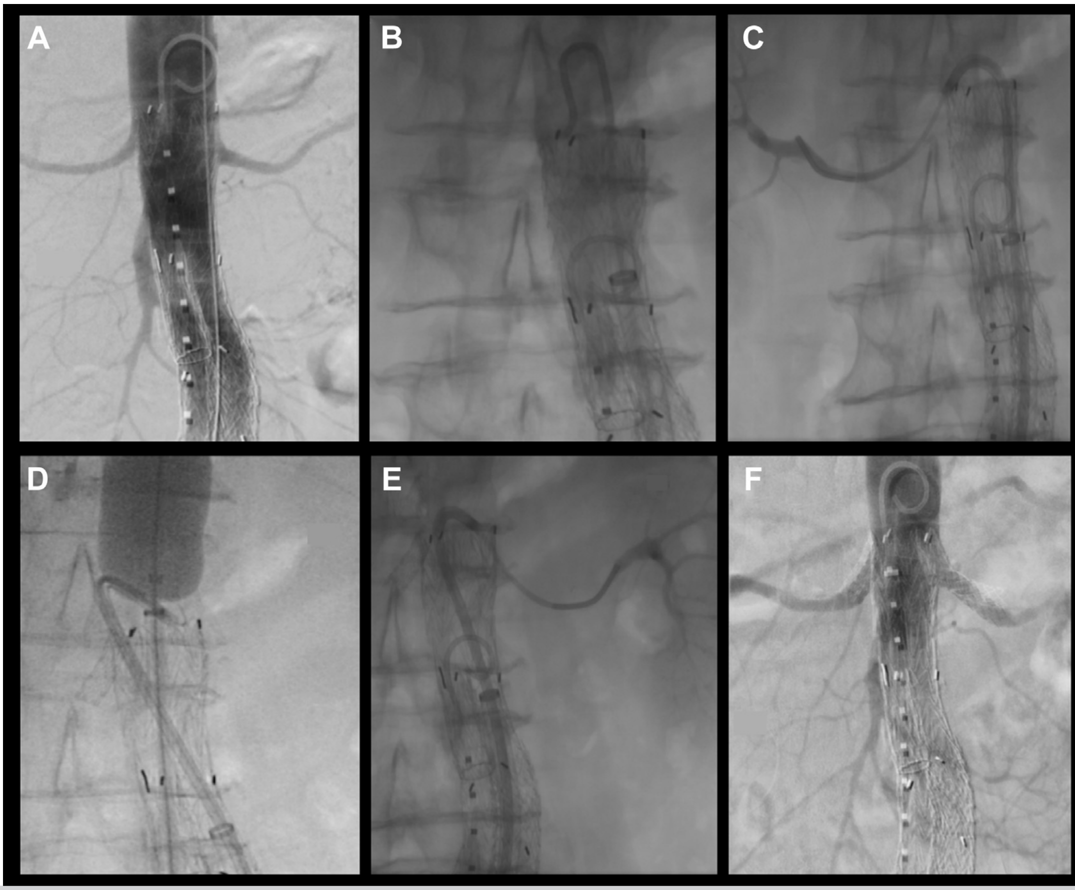

Fig 2. Fluoroscopic images obtained during endovascular abdominal aortic aneurysm repair (EVAR) for patient 2 of an infrarenal abdominal aortic aneurysm showing bailout bilateral renal artery cannulation. The C3 Excluder stent-graft was fully deployed and overlay both renal arteries **(A)**. **B,** A wisp of contrast can be seen in the lumen of the left renal artery, which could not be cannulated using conventional methods. **C,** A steerable Oscor sheath retracting the stent-graft fabric permitted access for cannulation. **D,** A combination of aortic balloon occlusion and Oscor sheath manipulation allowed the stent-graft fabric to be folded inferiorly, deflecting a wire off the balloon and into the now accessible renal artery **(E)**. **F,** Completion angiogram showing bilateral parallel renal stents and renal patency.

routinely used outside the aortic arch owing to the high incidence of chimney stent occlusion and type Ia endoleak seen in the infrarenal segment. Our local strategy has resulted in a persistent type Ia endoleak rate of $<2\%$.

We have presented two cases of accidental renal coverage due to stent migration. Folding of the proximal stent fabric inferiorly with a stiff steerable sheath provided adequate access for cannulation. Parallel grafting enabled flow into the vessels and preserved an adequate proximal seal on the stent-graft, without the need to access the arm or revert to maximally invasive emergency open surgery. A similar approach is the "encroachment" technique, in which the renal stent is placed to force the encroaching proximal edge of the aortic stent down toward the aneurysm.[6] Parallel and encroachment in the context of renal bailout have been well described in the current studies[6-15] (Table). Renal access in these cases was attained by direct cannulation of the vessels from either a femoral or brachial approach; none have mechanically altered the main body of the aortic stent-graft after deployment with steerable devices to permit arterial access. This technique might spare patients from time-intensive procedures using traditional catheter techniques that can contribute to further renal impairment, alternative upper extremity vascular access to improve angulation for renal artery cannulation, or even highly morbid emergency open surgical revascularization.

A simple approach for renal salvage would be to begin with a trial of retrograde catheterization via a femoral approach, to then attempt the technique we have described, and to next attempt antegrade catheterization via a transradial/brachial approach, before resorting to open repair. In these cases, the most described approach has been splenorenal and/or hepatorenal bypass with autologous vein or a PTFE graft.[3,10,19,21]

It is important to note that this fabric folding approach is also possible in stent-grafts that use suprarenal fixation

Table. A summary of the described cases of accidental renal coverage during endovascular abdominal aortic aneurysm repair (EVAR)

Investigator	Stent-graft used	Extent and side of accidental renal coverage	Intervention
Stelter et al,[16] 1997	Unknown	Unknown	Open explantation
Kalliafas et al,[17] 2000	Nottingham	Complete, unilateral	Hemodialysis
	Nottingham	Complete, unilateral	None
	Nottingham	Complete, unilateral	None
	Nottingham	Complete, bilateral	Graft pulled down with angioplasty balloon
van Dijk et al,[7] 2003	Excluder	Partial, right	Encroachment grafting
Böckler et al,[18] 2003	Ancure (12 cases)	Bilateral or unilateral	None or hemodialysis
	AneuRx (6 cases)		
	PowerLink (4 cases)		
	Lifepath (2 cases)		
	Stentor (16 cases)		
	Zenith (16 cases)		
Greenberg et al,[2] 2004	Zenith	Partial left, complete right	Left parallel grafting
	Zenith	Partial, bilateral	None
	Zenith	Partial left, complete right	Left parallel grafting
Reed et al,[8] 2004	AneuRx	Partial, bilateral	Encroachment grafting
	AneuRx	Partial, bilateral	Encroachment grafting
Katzen et al,[4] 2005	AneuRx	Complete, bilateral	Hemodialysis
Hedayati et al,[9] 2008	Zenith	Complete, right	Encroachment grafting
	Zenith	Partial left, complete right	Encroachment grafting
Hiramoto et al,[6] 2009	Zenith (11 cases)	Complete unilateral or partial unilateral	Encroachment grafting
Inan et al,[3] 2010	Anaconda	Complete, bilateral	Open aorto-birenal bypass
Hamish et al,[19] 2010	Endurant	Complete, bilateral	Open splenorenal, hepatorenal bypass
Adu et al,[10] 2012	Endurant	Complete, bilateral	Left parallel grafting
	Talent	Complete, bilateral	Open hepatorenal, splenorenal bypass
	Talent	Complete, bilateral	Open hepatorenal, splenorenal bypass
	Endurant	Complete left, partial right	Right parallel grafting
Kölbel et al,[20] 2013	Zenith + proximal Palmaz extension cuff	Complete, left	In situ fenestration with transseptal needle; renal stenting
Franchin et al,[11] 2014	Endurant	Complete, bilateral	Bilateral parallel grafting
Bracale et al,[12] 2014	E-vita	Complete, bilateral	Right parallel grafting; left open exposure, retrograde puncture, catheterization, stent placement
Terauchi et al,[13] 2014	Zenith Flex	Partial, right	Right encroachment grafting
Stanišić et al,[14] 2015	Zenith Flex	Partial, right	Right parallel grafting
Karakaş et al,[15] 2017	AFX	Complete, left (congenital solitary kidney)	Left encroachment grafting
Jessula et al,[21] 2017	Endurant II	Complete, bilateral	Open spleno-birenal bypass
Uehara et al,[22] 2019	Unknown	Complete, right (solitary functioning kidney)	Right renal autotransplantation

Nottingham, in-house custom-made device; Excluder, W. L. Gore and Associates Inc, Flagstaff, Ariz; Ancure, Guidant Corp, Indianapolis, Ind; AneuRx, Medtronic Inc, Santa Rosa, Calif; PowerLink, Endologix, Inc, Irvine, Calif; Lifepath, Baxter SA, Paris, France; Stentor, Boston Scientific, Natick, Mass; Zenith, Cook Medical, Bloomington, Ind; Anaconda, Vascutek/Terumo Inc, Inchinnan, UK; Endurant, Medtronic Inc, Santa Rosa, Calif; Talent, Medtronic Inc, Santa Rosa, Calif; E-vita, Jotec, Hechingen, Germany; Zenith Flex, Cook Medical, Bloomington, Ind; AFX, Endologix Inc, Irvine, Calif; Endurant II, Medtronic Inc, Santa Rosa, Calif; Palmaz, Cordis Corp, Bridgewater, NJ.

because it does not entail downward displacement of the fixation struts but the proximal fabric alone. We have used this technique in both the Anaconda (Vascutek/Terumo Inc, Inchinnan, UK) and Cook (Cook Medical) infrarenal devices in cases with partial renal encroachment.

REFERENCES

1. Zarkowsky DS, Hicks CW, Bostock IC, Stone DH, Eslami M, Goodney PP. Renal dysfunction and the associated decrease in survival after elective endovascular aneurysm repair. J Vasc Surg 2016;64:1278-85.
2. Greenberg RK, Chuter TA, Lawrence-Brown M, Haulon S, Nolte L; Zenith Investigators. Analysis of renal function after aneurysm repair with a device using suprarenal fixation (Zenith AAA endovascular graft) in contrast to open surgical repair. J Vasc Surg 2004;39:1219-28.
3. Inan K, Ucak A, Onan B, Temizkan V, Ugur M, Yilmaz AT. Bilateral renal artery occlusion due to intraoperative retrograde migration of an abdominal aortic aneurysm endograft. J Vasc Surg 2010;51:720-4.
4. Katzen BT, MacLean AA, Katzman HE. Retrograde migration of an abdominal aortic aneurysm endograft leading to postoperative renal failure. J Vasc Surg 2005;42:784-7.
5. Herman CR, Charbonneau P, Hongku K, Dubois L, Hossain S, Lee K, et al. Any nonadherence to instructions for use predicts graft-related adverse events in patients undergoing elective endovascular aneurysm repair. J Vasc Surg 2018;67:126-33.
6. Hiramoto JS, Chang CK, Reilly LM, Schneider DB, Rapp JH, Chuter TAM. Outcome of renal stenting for renal artery coverage during endovascular aortic aneurysm repair. J Vasc Surg 2009;49:1100-6.
7. van Dijk LC, van Sambeek MRHM, Cademartiri F, Pattynama PMT. Partial blockage of the renal artery ostium after stent-graft placement: detection and treatment. J Endovasc Ther 2003;10:684.
8. Reed AB, Mozes G, Carmo M, Andrews JC, Macedo TA, Gloviczki P. Renal artery coverage during endovascular aortic aneurysm repair: proximal migration or misplacement of the stent-graft? Perspect Vasc Surg Endovasc Ther 2004;16:135-40.
9. Hedayati N, Lin PH, Lumsden AB, Zhou W. Prolonged renal artery occlusion after endovascular aneurysm repair: endovascular rescue and renal function salvage. J Vasc Surg 2008;47:446-9.
10. Adu J, Cheshire NJ, Riga CV, Hamady M, Bicknell CD. Strategies to tackle unrecognized bilateral renal artery occlusion after endovascular aneurysm repair. Ann Vasc Surg 2012;26:1127.e1-7.
11. Franchin M, Fontana F, Piacentino F, Tozzi M, Piffaretti G. Postoperative "chimney" for unintentional renal artery occlusion after EVAR. Case Rep Vasc Med 2014;2014:170198.
12. Bracale UM, Giribono AM, Vitale G, Narese D, Santini G, del Guercio L. Accidental coverage of both renal arteries during infrarenal aortic stent-graft implantation: cause and treatment. Case Rep Vasc Med 2014;2014:710742.
13. Terauchi Y, Noguchi T, Tanioka K, Kubo T, Kitaoka H, Doi Y. A case of percutaneous transluminal renal angioplasty for partial coverage of a renal artery by a stent graft after endovascular aneurysm repair. Cardiovasc Interv Ther 2014;29:146-50.
14. Stanišić MG, Majewska N, Romanowski M, Kulesza J, Juszkat R, Makałowski M, et al. Endovascular treatment of renal artery occlusion caused by aortic stent-graft migration. Pol Przegl Chir 2015;87:181-4.
15. Karakaş MS, Korucuk N, Kemaloğlu C, Altekin RE, Demir İ. Renal artery occlusion in the late postoperative period managed with renal artery stenting after endovascular abdominal aortic aneurysm repair and renal function salvage. Turk Kardiyol Dern Ars 2017;45:462-5.
16. Stelter W, Umscheid T, Ziegler P. Three-year experience with modular stent-graft devices for endovascular AAA treatment. J Endovasc Surg 1997;4:362-9.
17. Kalliafas S, Albertini J-N, Macierewicz J, Yusuf SW, Whitaker SC, MacSweeney ST, et al. Incidence and treatment of intraoperative technical problems during endovascular repair of complex abdominal aortic aneurysms. J Vasc Surg 2000;31:1185-92.
18. Böckler D, Krauss M, Mannsmann U, Halawa M, Lange R, Probst T, et al. Incidence of renal infarctions after endovascular AAA repair: relationship to infrarenal versus suprarenal fixation. J Endovasc Ther 2003;10:1054-60.
19. Hamish M, Geroulakos G, Hughes DA, Moser S, Shepherd A, Salama AD. Delayed hepato-spleno-renal bypass for renal salvage following malposition of an infrarenal aortic stent-graft. J Endovasc Ther 2010;17:326-31.
20. Kölbel T, Carpenter SW, Diener H, Wipper S, Debus ES, Larena-Avellaneda A. Antegrade in situ stent-graft fenestration for the renal artery following inadvertent coverage during EVAR. J Endovasc Surg 2013;20:289-94.
21. Jessula S, Herman CR, Lee M, Lightfoot CB, Casey P. Salvage of bilateral renal artery occlusion after endovascular aneurysm repair with open splenorenal bypass. J Vasc Surg Cases Innov Tech 2017;3:163-6.
22. Uehara A, Suzuki T, Hase S, Sumi H, Hachisuka S, Fujimoto E, et al. Kidney autotransplantation for the treatment of renal artery occlusion after endovascular aortic repair: a case report. BMC Nephrol 2019;20:160.

Submitted Feb 10, 2021; accepted Apr 22, 2021.