The use of dynamic volumetric CT angiography (DV-CTA) for the characterization of endoleaks following fenestrated endovascular aortic aneurysm repair (f-EVAR)

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Accurate endoleak classification is essential following fenestrated endovascular aneurysm repair (f-EVAR). Both endoleak type and exact source of endoleak have implications upon the urgency and complexity of future management strategies. Herein we report on a patient with a documented endoleak post-f-EVAR, in which the source of blood flow into the aneurysm sac could not be determined using conventional computed tomographic angiography. Consequently, dynamic volumetric computed tomographic angiography (DV-CTA) was employed, which clearly illustrated the site of origin of the endoleak. DV-CTA enables accurate endoleak characterization following f-EVAR, with excellent conspicuity of the source of blood flow into the aneurysm sac. (J Vasc Surg 2010;51:203-6.)

The technique of fenestrated endovascular aortic aneurysm repair (f-EVAR) has been employed for treatment of both thoracoabdominal and abdominal aortic aneurysms with acceptable mid-term clinical outcome.[1-3] Fenestrated EVAR involves insertion of a custom-made device with fenestrations and branches to accommodate the visceral branches of the aorta. Through each fenestration or branch, additional stent grafts are placed to maintain visceral artery perfusion, while excluding the aortic aneurysm sac. Each additional stent graft placed increases the number of overlapping components and therefore the risk of a junctional leak. The presence of a junctional leak, known as a *type III endoleak*, confers a continued risk of aortic rupture due to exposure of the aneurysm sac to systemic arterial pressure. There is a consensus that type III endoleaks require treatment; however, due to the complexity of the custom-made stent graft implanted, the proximity and overlap of the branch vessels, accurate preprocedural imaging is essential to allow strategic management planning.

Computed tomographic angiography (CTA) has shown high sensitivity and specificity in the detection of endoleaks and is routinely used to follow up patients who have undergone conventional stent graft placement.[4,5] Despite high rates of endoleak detection, limited data exist regarding its use in the characterization of endoleak as a specific type. Consequently, digital subtraction angiography (DSA) remains the gold standard. However, these procedures can be challenging in patients with f-EVAR, requiring multiple arterial puncture sites and multiple contrast injections while occluding various branches and/or fenestrations, with consequent high contrast load and radiation dose. Dynamic volumetric computed tomographic angiography (DV-CTA) is a novel noninvasive technique that can be employed to characterize endoleak type and consequently prescribe appropriate treatment.

This report describes a patient who underwent f-EVAR and developed an endoleak identified but not accurately characterized by conventional CTA. Following four-dimensional (4D) DV-CTA, a type III endoleak was diagnosed along with the exact site of origin.

REPORT

A 59-year-old male underwent f-EVAR for a type II thoracoabdominal aneurysm with use of a custom-made stent graft (Cook Inc, Bloomington, Ind). Past medical history included hypertension and left nephrectomy for benign cystic renal disease. A left carotid-subclavian artery bypass was performed prior to the procedure during a single anesthetic.

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Fig 1. Completion angiography post f-EVAR, focusing on the visceral segment of the stent graft, demonstrates no evidence of contrast extravasation. Imaging suggests complete exclusion of the aneurysm sac. *f-EVAR,* Fenestrated endovascular aortic aneurysm repair.

Device characteristics and implantation. The custom-made device incorporated a fenestrated component with branches for the celiac and superior mesenteric arteries and one fenestration for the right renal artery. Stent grafts placed included a Fluency Plus stent graft (CR Bard, Tempe, Ariz) with an 18-mm junctional overlap inside the aortic stent graft branch, reinforced with a Zilver bare metal stent (Cook Inc) to prevent stent graft kinking, for both the celiac and superior mesenteric arteries; and a 7-mm-diameter by 16-mm-length Advanta V12 (Atrium Medical Corporation, Hudson, NH) balloon-mounted stent graft flared proximally with a 10-mm-diameter by 20-mm-length Diamond angioplasty balloon (Boston Scientific Corp, Natick, Mass) for the right renal artery. Completion angiography revealed satisfactory positioning of the components of the stent graft, with complete exclusion of the aneurysm and no evidence of endoleak (Fig 1).

Follow-up CTA imaging was performed at 1 month, as per standard institutional protocol, using a 64 detector CT scanner (Aquilion 64; Toshiba, Tokyo, Japan). Unenhanced images were acquired, followed by arterial phase and delayed phase images after intravenous injection of iso-osmolar non-ionic iodinated contrast (Visipaque 270; GE Healthcare, Milwaukee, Wis). CTA revealed significant contrast extravasation into the aneurysm sac at the fenestrated segment of the stent graft (Fig 2). This was presumed to represent a type III endoleak, but the exact source of endoleak could not be determined.

Dynamic volumetric CTA technique. DSA to delineate an endoleak would have been technically challenging in this patient for a number of reasons, including:

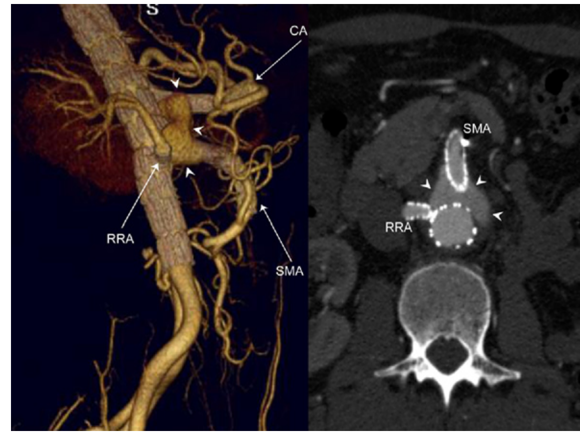

Fig 2. Sagittal oblique volume-rendered and axial source CTA images 1 month post-f-EVAR. Sagittal oblique volume-rendered CTA from a right-sided projection demonstrates a large endoleak (*white arrowheads*) involving the visceral segment of the abdominal aortic stent graft: celiac artery (*CA*), superior mesenteric artery (*SMA*), and right renal artery (*RRA*). Exact site of endoleak could not be identified. Axial source CTA image provides the same information. CTA, Computed tomographic angiography; *f-EVAR,* fenestrated endovascular aortic aneurysm repair.

1. The requirement of more than one arterial puncture to enable both balloon insertion for branch or fenestration occlusion during contrast injection and angiographic catheter insertion to perform DSA.
2. The requirement of a brachial arterial puncture to cannulate branches, which are craniocaudal in orientation — which in turn has an increased risk of postoperative hematoma and arterial thrombosis.
3. Endoleaks may be of slow flow, making them difficult to identify.
4. Endoleaks may require multiple projections to detect their exact source. Consequently, this may lead to high radiation and contrast doses, in addition to an increased risk of puncture site complications.

Due to such technical challenges, it was elected to perform a DV-CTA using a 320 detector CT scanner (Aquilion One; Toshiba). The scanner has a 16-cm-long detector, which is capable of scanning in non-helical fashion at a rate of up to three rotations per second.

Initially, 5-mm axial non-contrast images were acquired for localization. This was followed by a low-dose test bolus to determine contrast medium transit time.

Four-D DV-CTA was performed with a second injection of 80 mL of contrast at 5 mL/sec, followed by a saline bolus chase of 30 mL, also at 5 mL/sec. A mask image was obtained immediately after initiation of contrast injection. Dynamic scanning was initiated at the time contrast initially reached the top of the stent graft and continued for a total of 18 seconds using the following parameters: scan range 16 cm, gantry rotation time 0.5 seconds, tube voltage 120 kVp, tube current 300 mA, and 1-mm section thickness. The scan was performed with continuous tube activation,

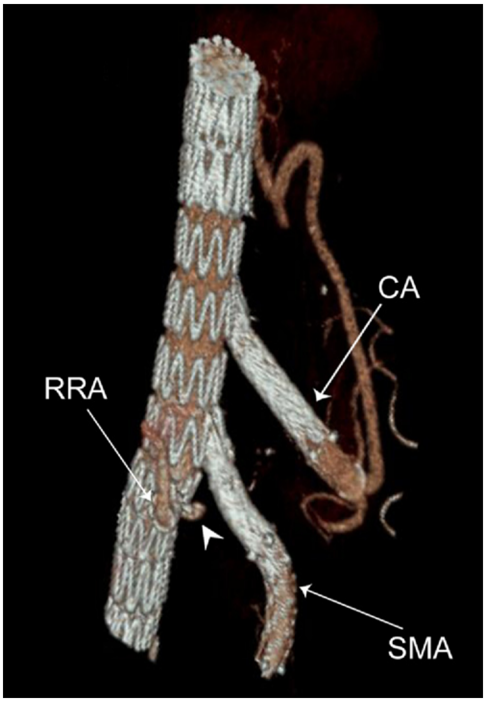

Fig 3. Single image from a sagittal oblique volume-rendered cine loop illustrating extravasation of contrast at the junctional overlap of the right renal artery (*RRA*) fenestration and the implanted Advanta V12 RRA stent graft, indicative of a type III endoleak (*arrowhead*). The type III endoleak was thought to be secondary to lateral slippage of the RRA stent graft. *CA*, Celiac artery; *SMA*, superior mesenteric artery.

and images were reconstructed to a temporal resolution of two frames per second.

Postprocessing was completed on the Aquilion One console and was also transferred to a dedicated postprocessing workstation (Vitrea FX, Vital Images, Minneapolis, Minn) for creation of 4D digital subtraction CTA images as well as 3D and thin-section maximum-intensity projection cine loops (Figs 3 and 4, Videos 1 and 2).

CTA imaging findings. DV-CTA clearly demonstrated a type III endoleak originating from the anterior aspect of the right renal fenestration, likely due to lateral slippage of the renal stent graft.

Secondary intervention. Following accurate delineation of endoleak source, it was elected to treat the type III endoleak via a transfemoral approach. A 6- to 12-mm diameter by 17-mm-length Jostent stent graft (Jomed; Abbott Vascular Devices, Rangendingen, Germany) was hand-crimped onto a 7-mm-diameter by 20-mm-length Diamond angioplasty baloon (Boston Scientific Corp). The stent graft was introduced via a 10 F vascular sheath (Avanti; Cordis Endovascular, Miami, Fla) alongside a 4 F pigtail catheter to guide stent graft placement and deployed within the right renal fenestration Advanta V12 stent graft in situ. Following stent graft deployment, the proximal stent graft was flared using a 10-mm-diameter by 20-mm-length Diamond balloon to ensure adequate seal and prevent migration. Endoleak exclusion was confirmed on subsequent conventional CTA imaging.

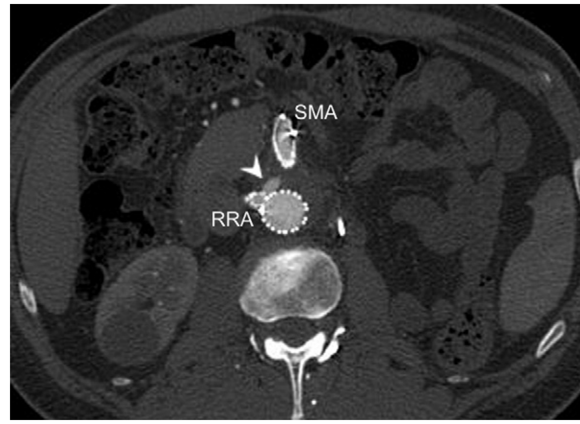

Fig 4. Single image from 4D dynamic imaging centered at the level of the right renal artery (*RRA*) stent graft, showing extravasation of contrast anteriorly depicting a type III endoleak (*arrowhead*). *SMA*, Superior mesenteric artery.

DISCUSSION

This case report demonstrates the usefulness of DV-CTA in classification of endoleaks following f-EVAR. This is of critical importance as diagnosis frequently dictates the approach to intervention and also its urgency. Type I and III endoleaks constitute a major complication requiring early treatment, as persistent high-pressure perfusion into the aneurysm sac could potentially lead to aortic rupture.

Endoleaks following conventional EVAR occur in up to 50% of patients.[6-9] Until now, endoleaks observed have commonly been type I and II. As the utilization of f-EVAR increases, the risk and incidence of type III endoleak may rise due to the multinodular nature of these stent grafts.[2]

At present, conventional CTA continues to be the most common study performed for endoleak detection in the follow-up of f-EVAR. Despite its high sensitivity and specificity, standard CTA protocols have been shown to be suboptimal for endoleak classification.[10] This is in part due to an inherent limitation of standard CTA, which is a static image without information about dynamics of flow. The technique of DV-CTA overcomes this limitation of standard CTA, allowing imaging of the aneurysm sac in a continuous fashion, thereby capturing the source of endoleak prior to contrast opacification of the aneurysm sac. Consequently, DV-CTA obviates the need for supplemental invasive investigative techniques, such as angiography, necessary to prescribe appropriate treatment. Potential disadvantages of both CTA and DV-CTA include exposure to ionizing radiation and the potential for contrast-induced nephropathy. In addition, this novel DV-CTA technique requires a 320-detector CT scanner for its 16-cm field of view dynamic capabilities, which is the newest-generation CT scanner on the imaging market, and of limited availability.

The use of contrast-enhanced or color-flow duplex ultrasound (CDU) and time-resolved magnetic resonance angiography in the classification of endoleaks post-EVAR have both been investigated.[11-13] CDU can accurately show change in aneurysm size over time but has a low sensitivity and positive predictive value in endoleak detection and classification.[11,12] Time-resolved magnetic resonance angiography (MRA) has been shown to be an effective noninvasive method for classification of endoleaks,[13] but its use is limited to nitinol-based devices. Since the only currently available fenestrated stent grafts are manufactured by Cook Inc, and use a stainless steel skeleton, patients with f-EVAR cannot be evaluated with MRA.

In conclusion, 4D CTA shows promise as a means of illustrating the type and source of endoleak in patients with complex aortic reconstructions, when endoleak origin cannot be defined by standard CTA imaging. It combines high spatial and temporal resolution in a single noninvasive imaging study. Further studies are required to define its exact role in the follow-up of patients with complex aortic stent grafts, but in selected cases, it could be extremely valuable in providing noninvasive information that facilitates planning of endoleak management.

AUTHOR CONTRIBUTIONS

Conception and design: CB, JJ, KT
Analysis and interpretation: CB, JJ, KT
Data collection: CB
Writing the article: CB
Critical revision of the article: JJ, TL, KT
Final approval of the article: JJ, TL, KT
Statistical analysis: N/A
Obtained funding: N/A
Overall responsibility: CB

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