Use of three-dimensional contrast-enhanced duplex ultrasound imaging during endovascular aneurysm repair

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Background: **Iodinated contrast during endovascular aneurysm repair (EVAR) is used with caution in patients with chronic kidney disease. Contrast-enhanced ultrasound (CEUS) imaging using nonnephrotoxic sulphur hexafluoride microbubble contrast is a novel imaging modality that accurately identifies and characterizes endoleaks during EVAR follow-up. We report our initial experience of using three-dimensional (3D) CEUS imaging intraoperatively as completion imaging after endograft deployment. Our aim was to compare intraoperative 3D CEUS against uniplanar angiography in the detection of endoleak, stent deformity, and renal artery perfusion during EVAR.**

Methods: **The study enrolled 20 patients undergoing elective conventional infrarenal EVAR, after which a completion angiogram was performed and the presence of endoleak, renal artery perfusion, or device deformity were recorded. With the patient still under anesthetic, a vascular scientist blinded to angiographic findings performed 3D CEUS and reported on the same parameters.**

Results: **Three endoleaks, one type I and two type II, were detected on uniplanar angiography and 13 endoleaks, 11 type II and two type I, were found using 3D CEUS imaging. Of note, one of these type I endoleaks was not seen on angiography, and this patient underwent balloon moulding of the neck with resolution of the endoleak on repeat imaging. Of the 11 type II endoleaks seen with 3D CEUS imaging, the inflow vessel was identified in nine cases. No graft deformity or limb kinking was seen in any patient. Both renal arteries could be visualized in 10 patients, whereas the target renal artery was seen in 11 patients. In the remaining patients, the renal arteries could not be visualized, mainly due to intra-abdominal gas or patient body habitus.**

Conclusions: **3D CEUS imaging detected endoleaks not seen on uniplanar digital subtraction angiography, including a clinically important type I endoleak, and was also more sensitive than 2D CEUS imaging for the detection of the source of endoleak. This technology has the potential to supplement or replace digital subtraction angiography for completion imaging to reduce the use of x-ray contrast. Intraoperative 3D CEUS has been applied to allow safe EVAR with ultralow or no iodinated contrast usage in selected cases, without compromising completion imaging. (J Vasc Surg 2014;60:1468-72.)**

Endovascular aneurysm repair (EVAR) has reduced the incidence of postoperative mortality compared with open repair,[1] although EVAR may be complicated by acute kidney injury due to maldeployment, renal microembolization, or the use of iodinated contrast (IC) media. IC can result in short-term and long-term contrast-induced nephropathy, particularly in patients with underlying chronic kidney disease (CKD), and is contraindicated in those who are allergic to iodine.[2,3]

Standard endograft deployment technique uses digital subtraction angiography (DSA) with IC media to aid intra-arterial navigation and to provide quality-assurance completion imaging to examine for the presence of endoleaks, visceral vessel patency, and endograft integrity. Although an essential element of safe endograft deployment, completion imaging significantly contributes to the total IC load, especially if several angiographic runs are required. Carbon dioxide (CO_2) has been used as a non-nephrotoxic alternative to IC,[4] but its utility is limited to endograft deployment because CO_2 does not provide adequate image quality for completion quality control.[5]

The role of contrast-enhanced ultrasound (CEUS) imaging in the context of post-EVAR surveillance has gained acceptability in recent years[6-9] because it presents a cost-effective alternative to computed tomography (CT) that does not necessitate nephrotoxic IC or ionizing radiation. CEUS imaging uses non-nephrotoxic sulphur hexafluoride microbubbles as contrast, which are completely eliminated through the lungs. Three-dimensional (3D) CEUS is an evolution of this technology that uses positional information from magnetic field emitters to place and orientate the ultrasound transducer probe precisely in space to allow dynamic interrogation of an endograft from any angle within the aneurysm. A pilot study from our institution showed that 3D CEUS has accuracy comparable to or better than CT to detect endoleaks during post-EVAR follow-up.[10]

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Table I. Patient demographics

Age, years	*Sex*	*BMI, kg/m²*	*Aneurysm size, cm*	*Current smoker*	*Diabetes*	*SBP, mm Hg*	*DBP, mm Hg*	*Creatinine, μmol/L*	*EVAR device*
70	M	33.6	7.2	No	No	128	79	175	Cook LP[a]
86	M	27.8	6	No	No	160	80	109	Endurant II[b]
74	M	26.1	7.8	No	No	171	74	118	Zenith[a]
72	M	30.5	5.6	No	No	130	90	115	Endurant II[b]
77	M	25.2	6.1	Yes	No	161	95	213	Ovation[c]
66	M	32.7	5.5	No	No	124	83	71	Endurant II
75	M	30.4	5.7	No	No	127	72	120	Endurant II
68	M	23.1	8.4	No	No	150	70	83	Endurant II
79	M	29.8	6.4	No	No	193	93	102	Ovation
79	M	24.0	5.7	No	No	142	65	59	Endurant II
64	M	30.0	6.7	No	No	151	80	66	Aorfix[d]
86	F	26.4	5.5	No	No	131	63	83	Ovation
84	M	30.1	5.5	No	No	118	68	84	Endurant II
88	F	28.3	5.8	No	Yes	110	40	72	Endurant II
74	M	32.2	7.1	No	No	137	68	83	Endurant II
81	M	20.0	4.2 (iliac)	Yes	Yes	128	64	66	Endurant II
72	M	26.0	5.3	No	No	162	80	129	Endurant II
83	M	27.2	5.7	No	No	165	74	69	Endurant II
86	M	29.0	6.1	No	No	128	61	102	Anaconda[e]
75	M	29.0	9.5	No	No	142	48	107	Endurant II

BMI, Body mass index; *DBP,* diastolic blood pressure; *F,* female; *M,* male; *SBP,* systolic blood pressure.
[a]Cook, Bloomington, Ind.
[b]Medtronic, Minneapolis, Minn.
[c]TriVascular, Santa Rosa, Calif.
[d]Lombard Medical Technologies PLC, Oxfordshire, UK.
[e]Sulzer Vascutech, Bad Soden, Germany.

Intraoperative use of this technology gives the potential to visualize stent graft positioning and endoleak immediately after deployment while reducing the overall requirement of IC media. Thus, intraoperative CEUS potentially has clinical utility in patients with chronic renal impairment or when CO_2 is used the primary contrast medium. The aim of this feasibility study was to assess the clinical utility of 3D CEUS for intraoperative completion imaging after EVAR as an alternative to conventional uniplanar catheter angiography for the detection of endoleak, endograft deformity, and renal artery patency.

METHODS

The study prospectively enrolled 20 patients undergoing elective infrarenal EVAR under the care of a single surgeon. The local ethics committee approved the project, and the patients gave informed consent. All patients were initially seen in the clinic and reviewed by a consultant vascular surgeon. Suitability for EVAR was determined from an initial CT scan using IC. The morphologic characteristics of the aneurysm and access vessels were reviewed at a multidisciplinary team meeting.

All patients underwent EVAR deployment while under general anesthesia in a vascular operating theater with mobile C-arm imaging. After endograft deployment, a standard completion uniplanar DSA was done using 20 mL full-strength iodixanol contrast (Visipaque 270; GE Healthcare, Hertfordshire, UK) injected at 10 to 15 mL/s. The presence of endoleak, renal artery perfusion, and device deformity were recorded. Endoleaks were characterized by type and source. Renal artery perfusion and presence of graft deformity were also noted. With the patient still anesthetized, an accredited vascular scientist with specific training in 3D CEUS attended the theater. This individual, who was blinded to the angiographic findings, performed conventional 2D and 3D CEUS imaging to measure the same parameters.

The 3D CEUS was undertaken with a Phillips IU22 ultrasound console (Phillips, Amsterdam, Netherlands) using a C5 2-MHz curved array probe. Then, 1-mL boluses of sodium hexafluoride (SonoVue, Bracco, Italy) were administered intravenously to a maximum of 5 mL. The images acquired were processed using a Curefab CS 3D system (Curefab, Munich, Germany) and were replayed and manipulated to identify endoleaks. The 3D CEUS findings were then verbally relayed to the team performing the EVAR and recorded. If necessary, any interventions based on the 3D CEUS findings were then undertaken.

The recorded outcome measures were presence of an endoleak, type of endoleak, inflow vessel of endoleak, renal artery visualization and patency, and evidence of limb kinking.

RESULTS

The study included 20 consenting patients, and their demographics are given in Table I. Of these patients, 19 underwent EVAR for infrarenal abdominal aortic aneurysm, including 18 bifurcated stent grafts and one aortouniiliac