Could Four-dimensional Contrast-enhanced Ultrasound Replace Computed Tomography Angiography During Follow up of Fenestrated Endografts? Results of a Preliminary Experience

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WHAT THIS PAPER ADDS
Computed tomography angiography is the gold standard for fenestrated endovascular aneurysm repair (FEVAR) follow up. Radiation, the nephrotoxic contrast, and costs limit its use. The data herein suggest an alternative protocol for FEVAR follow up in selected patients.

Objective: To evaluate four-dimensional contrast-enhanced ultrasound (4D-CEUS) as an alternative imaging method to computed tomography angiography (CTA) during follow up of fenestrated endovascular aneurysm repair (FEVAR) for juxta- and para-renal abdominal aortic aneurysms (AAA).
Methods: Between October 2011 and March 2012, all consecutive patients who underwent FEVAR follow up were included in the study and evaluated with both 4D-CEUS and CTA. The interval between the two examinations was always ≤30 days. Endpoints were the comparison of postoperative AAA diameter, AAA volume, presence of endoleaks, revascularized visceral vessel (RVV) visualization, and patency. Comparative analysis was performed using Bland—Altman plots and McNemar's Chi-square test.
Results: Twenty-two patients (96% male, 4% female; mean age 74 ± 7 years; American Society of Anesthesiologists grade III/IV 82%/18%) were enrolled. Seventy-eight RVV (fenestrations: 60; scallops: 17; branches: 1) were analyzed. The mean AAA diameter evaluated by 4D-CEUS and CTA was 45 ± 10 mm (range 30—69 mm) and 48 ± 9 mm (range 32—70 mm), respectively. The mean difference was 3 ± 3 mm. The mean AAA volume evaluated by 4D-CEUS and CTA was 150 ± 7 cc (range 88—300 cc) and 159 ± 68 cc (range 80—310 cc), respectively. The mean difference was 7 ± 4 cc; a Bland—Altman plot revealed agreement in AAA diameter and volume evaluation ($p < .01$) between 4D-CEUS and CTA. The observed agreement for the detection of endoleaks was 95%. McNemar's Chi-square test confirmed that 4D-CEUS and CTA were equivalent ($p > .05$) at detecting endoleaks. The first segment of six (8%) RVVs (four renal and two superior mesenteric arteries) was not directly visualized by 4D-CEUS owing to obesity, but the contrast enhancement into the distal part of vessel or into the relative parenchyma gave indirect information about their patency. McNemar's Chi-square test demonstrated the superiority of CTA ($p = .031$) in visualizing RVVs. The patency of 77/78 RVVs was confirmed with both techniques. McNemar's Chi-square test confirmed that 4D-CEUS and CTA were equivalent in their ability to detect visceral vessel patency.
Conclusions: The data suggest that 4D-CEUS is as accurate as CTA in the evaluation of postoperative AAA diameter and volume, endoleak detection, and RVV patency after FEVAR. Four-dimensional CEUS could provide hemodynamic information regarding RVVs, and reduce radiation exposure and renal impairment during follow up. Obesity limits the diagnostic accuracy of 4D-CEUS.

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INTRODUCTION

Single- and multicentre experience has suggested that fenestrated endovascular aneurysm repair (FEVAR) is a well established therapeutic option to treat juxta- and para-renal abdominal aortic aneurysms (AAAs) with low mortality/morbidity and satisfactory intermediate outcomes.[1—3]

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Endovascular aneurysm repair has been associated with a higher incidence of secondary interventions due to complications, that in the case of FEVAR include endoleaks, migration, and target vessel or iliac leg occlusions.[4—6] Strict follow up is therefore mandatory to detect and correct these complications. Nowadays, computed tomography angiography (CTA) is considered the gold standard for FEVAR follow up,[1—3,6] but the cumulative radiation dose, nephrotoxic contrast agent use, and high cost limit its use as a lifelong surveillance tool.

Contrast-enhanced ultrasound (CEUS) has a high sensibility and specificity in detecting and classifying endoleaks in standard EVAR follow up,[7—10] and a recent study suggests its use for FEVAR evaluation.[11] Real-time four-dimensional (4D) ultrasound (US) is available on new probes with matrix-array, “fully sampled” technology, and its use has been reported in cardiology, obstetrics, and interventional radiology.[11—14] Real-time 4D CEUS (4D-CEUS) imaging is a new medical imaging technique that combines CEUS and 4D US to overcome the shortcomings of incomplete scanning of two-dimensional US images.

There are no data with regard to its application after FEVAR. The aim of this study was to evaluate 4D-CEUS as an alternative imaging method to CTA during the follow up of fenestrated endografts for AAA.

METHODS

From October 2011 to March 2012, all consecutive patients who underwent FEVAR follow up for juxta- and para-AAA (neck length <0.5 mm) were prospectively enrolled.

FEVAR procedures were performed in a dedicated operating theatre with a C-arm OEC 9800 plus (GE Healthcare, Salt Lake City, UT, USA) and the fenestrations were joined to the native visceral vessels with a balloon-expandable covered stent-graft (Advanta V12, Atrium Medical, Hudson, NH, USA). Indications for FEVAR included asymptomatic high surgical risk patients with juxta-/para-renal AAA with a diameter between 55 and 70 mm, juxta-/para-renal AAA with a diameter between 50 and 54 mm associated with aortic blister, AAA growth rate of >0.5 cm/year, or penetrating aortic ulcer with a diameter of >35 mm. The exclusion criteria were proximal aortic neck angle >60°; iliac or common femoral artery stenotic or occlusive lesions; severe tortuous iliac arteries; visceral vessels with a diameter of <4 mm; or severe stenosis (>70%).

Patients were evaluated with both CEUS/4DCEUS and CTA. The interval between the two examinations was always ≤30 days. Patients signed a specific consent form for this follow up protocol.

The study endpoints were the comparison of postoperative AAA diameter, AAA volume, the presence of endoleaks, visualization and patency of revascularized visceral vessels (RVVs).

CTA

CTA was performed by a radiologist with experience in vascular CTA evaluations (MD). Triple-phase CTA (unenhanced, arterial contrast-enhanced, and delayed phases [180 seconds]) was acquired on a 64-slice CT scanner (GE Healthcare) from the thorax to the femoral artery bifurcations. Iodinate contrast (100—130 mL Iomeron 400; Bracco, Milan, Italy) was injected at 4 mL/second for the first 100 mL and 2 mL/second for the last 30 mL. Contrast injection was followed by saline solution (0.9% NaCl) at a rate of 2 mL/second. Reconstructions at a slice thickness of 1 mm were performed. Patients with creatinine >1.3 mg/dL received intravenous hydration the day before and after CTA. Patients with a history of allergy to the iodinated contrast were pre-medicated with corticosteroids and antihistamines before the examination. The CTA was processed on independent dedicated software for visceral vessel analysis (3Mensio; Vascular Imaging, Bilthoeven, the Netherlands), and evaluated by radiologists and vascular surgeons expert in endovascular aneurysm repair (EVAR) and FEVAR planning and procedures. The postoperative AAA diameters and volumes were measured using center lumen line reconstructions. Endoleaks were detected and classified according to the White and May classification.[15] Visualization and patency of the RVV was determined on the axial CTA cuts and appropriate post-processing reconstructions.

CEUS/4D-CEUS

All US examinations, including baseline US, CEUS, and 4D-CEUS, were performed with the same machine (iU22 system, software Q-Lab; Philips Medical Systems, Bothell, WA, USA). A fully sampled matrix array with a frequency of 6.0—1.0 MHz (x6-1; Philips Medical Systems) was used.

A sulfur hexafluoride-filled microbubble contrast agent (SonoVue; BR1, Bracco) was used for contrast examinations.

To avoid interobserver variability, all US scanning was performed by one investigator (CS) who had more than 10 years of experience in contrast ultrasound and who was blinded to the CTA.

The US examination started with B-mode evaluation of the aorta by live *x*-plane imaging where the maximal aneurysm diameter and the stent-graft were evaluated. The abdominal aorta was scanned from the diaphragm to the iliac arteries and the entire sac was analyzed to detect possible color flow within the aneurysm sac. Then, the blood flow in the visceral and renal arteries was analyzed in color flow and pulse-wave modes. Fifty percent or greater stenosis of a stented vessel was considered significant and was identified using the pick systolic velocity and vessels/aortic systolic ratio defined by Aburama et al.,[16] as velocities in stented vessels tend to be higher than in native vessels.

In the CEUS mode, the unenhanced and enhanced images were displayed simultaneously on the same screen (side-by-side technique) to identify the aorta and the collaterals previously evaluated with B-mode and Doppler US. SonoVue (Bracco) was injected into the antecubital vein as a 2.5-mL bolus (within 1—2 seconds), followed by a flush of 10 mL normal saline. The timer was activated promptly from the beginning of injection. The aorta was observed for at least 2