Eur J Vasc Endovasc Surg (2015) 49, 390–395

Intra-operative Cone Beam Computed Tomography can Help Avoid Reinterventions and Reduce CT Follow up after Infrarenal EVAR

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WHAT THIS PAPER ADDS

This paper highlights the intra-operative effects of cone beam computed tomography (CT) by improving the technical outcome of endovascular aneurysm repair (EVAR), and also questions the need of routine early CT angiography after EVAR.

Objective/Background: Re-interventions after endovascular abdominal aortic aneurysm repair (EVAR) are common and therefore a strict imaging follow up protocol is required. The purpose of this study was to evaluate whether cone beam computed tomography (CBCT) can detect intra-operative complications and to compare this with angiography and the 1 month CT follow up (computed tomography angiography [CTA]).

Methods: Fifty-one patients (44 men) were enrolled in a prospective trial. Patients underwent completion angiography and CBCT during infrarenal EVAR. Contrast was used except when pre-operative renal insufficiency was present or if the maximum contrast dose threshold was reached. CBCT reconstruction included the top of the stent graft to the iliac bifurcation. Endoleaks, kinks, or compressions were recorded.

Results: CBCT was technically successful in all patients. Twelve endoleaks were detected on completion digital subtraction angiography (CA). CBCT detected 4/5 type 1 endoleaks, but only one type 2 endoleak. CTA identified eight type 2 endoleaks and one residual type I endoleak. Two cases of stent compression were seen on CA. CBCT revealed five stent compressions and one kink, which resulted in four intra-operative adjunctive manoeuvres. CTA identified all cases of kinks or compressions that were left untreated. Two of them were corrected later. No additional kinks/compressions were found on CTA. Groin closure consisted of 78 fascia sutures, nine cut downs, and 11 percutaneous sutures. Seven femoral artery pseudoaneurysms (<1 cm) were detected on CTA, but no intervention was needed.

Conclusion: CA is better than CBCT in detecting and categorizing endoleaks but CBCT (with or without contrast) is better than CA for detection of kinks or stentgraft compression. CTA plus CBCT identified all significant complications noted on the 1 month follow up CTA. The use of intra-operative CA and CBCT could replace early CTA after standard EVAR thus reducing overall radiation and contrast use. Technical development might further improve the resolution and usefulness of CBCT.

Article history: Received 4 September 2014, Accepted 16 January 2015, Available online 27 February 2015

Keywords: Cone beam CT, DynaCT, EVAR, Re-interventions

INTRODUCTION

Endovascular repair of abdominal aortic aneurysm (EVAR) is the primary treatment option in anatomically suitable patients. Previous reports of EVAR have demonstrated a significant risk of secondary interventions for endoleaks, migrations, and stent graft failure, including aneurysm rupture. This has prompted the need for extensive post-operative follow up (FU). The gold standard for FU is contrast enhanced computed tomography angiography (CTA). However, this method exposes the patients to radiation, as well as contrast, which might lead to radiation induced malignancy and contrast induced renal nephropathy, respectively.[1,2] Ultrasound FU has therefore been used increasingly, but is limited in detecting structural problems with an endograft, such as kinks, migrations, and fractures.[3] Combined programmes with an early CTA and subsequent ultrasound have also been proposed, as an uneventful CTA is associated with improved late outcomes.[4] The development of intra-operative cross sectional imaging techniques such as cone beam computed tomography (CBCT) have been shown to be feasible both in EVAR planning and as completion imaging to detect complications missed by conventional angiography.[5,6]

The aim of this study was to evaluate the efficacy of completion CBCT in detecting intra-operative complications compared with standard final angiography. In addition,

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http://dx.doi.org/10.1016/j.ejvs.2015.01.009

completion CBCT was compared with the 1 month CTA to evaluate the use of CBCT alone as the primary modality for early post-operative imaging.

METHODS

The Regional Ethical Committee at Lund University approved the study and all patients gave written informed consent prior to enrolment. Fifty-one patients undergoing standard infrarenal EVAR were enrolled prospectively between October 2012 and December 2013. Two patients were excluded from analysis because of incomplete FU. Mean age was 72 years (range 57—91 years) and 43 were men. Patient mean body mass index was 26.8 (range 19.5—44.7). Stent grafts included the Zenith Flex (Cook Medical Inc., Bloomington, IN, USA; $n = 42$), Endurant (Medtronic Inc., Minneapolis, MN, USA; $n = 3$), Zenith LP (Cook Medical; $n = 2$) and Trivascular Ovation (Trivascular Inc., Santa Rosa, CA, USA; $n = 2$). All procedures were performed in an operating room equipped with a fixed ceiling mounted imaging system (Siemens Artis Zee; Siemens, Munich, Germany). After EVAR placement and balloon moulding of the stent graft, completion digital subtraction angiography (CA) was performed using a standard institutional protocol. A pigtail catheter was placed at the level of the renal arteries and 20 mL contrast injected in an antero-posterior projection at 20 mL/second using a power injector.

CBCT (DynaCT; Siemens) was performed intra-operatively after CA but before groin closure. CBCT included contrast enhancement, except in the presence of renal insufficiency or if the maximum contrast dose threshold was reached according to the OmniVis software (GE Healthcare) based on patients' glomerular filtration rate (GFR). CBCT was performed using Visipaque (GE Healthcare, Little Chalfont, UK) 140 mg/mL (9 mL/second for a total dose of 72 mL). CA and CBCT were both performed with apnoea.

The positioning of the detector (40 × 30 cm) was initially in horizontal mode during an 8 second rotation of 200 degrees, 0.5 degrees angular increment. With this setup, the entire stentgraft could often not be included, and the operator had to determine the area of greatest interest proximally or distally, to be included in the CBCT. This issue has been described earlier and has been a major limitation of the technique.[7,8] A software upgrade during the trial enabled a vertical (portrait) mode, which is superior in studying the stent graft. The detector is simply rotated 90 degrees thus allowing capture of a greater cranio-caudal segment (30 × 40 cm). The remaining CBCT protocol remained unchanged. Before a CBCT run, all guide wires were exchanged for catheters to reduce image artifacts (scatter).

The operator assessed the CA and the CBCT only after both had been completed. Imaging after processing with multiplanar reconstructions, maximum intensity projection, and three dimensions were performed at the operator's discretion using Inspace software (Siemens). Intra-operative adjunctive procedures to solve any additional findings noted on CBCT or CA were done at the discretion of the operator. The result was reviewed with the same modality that had demonstrated the finding (additional CBCT or DSA).

All patients underwent three phase CTA 4—6 weeks post-operatively according to a standard protocol. The FU CTA protocol was performed with a Somatom Sensation 16 Scanner (Siemens) using Omnipaque 350 mg/mL, 120 mL during a 15 second injection. The scanning was performed in three phases. One pre-contrast scan was followed by an arterial phase scan. Finally, the late venous phase was performed after an 80 second delay. The area of interest was between xiphisternum and lesser trochanter. CTAs were evaluated by the EVAR operator and were compared with the intra-operative CBCT findings.

The main purpose was to evaluate the peri-operative complications identified by CBCT in relation to CA and to determine whether the 1 month CTA identified additional complications.

Anatomical details

All cases were measured by center line calculations using the Aquarius iNuition program (Terarecon Inc., Foster City, CA, USA). Abdominal aortic aneurysm (AAA) diameters were measured by the same observer using the shortest transverse diameter at the widest point of the aneurysm sac and at the proximal neck of abdominal aorta. The mean aneurysm diameter was 56.2 × 61.0 mm (range 21.0—10.0 mm). The aortic neck diameter at the lowest renal artery was a mean of 22.3 × 23.3 mm (range 17.0—30.0 mm). The mean aortic diameter 15 mm below the lowest artery was 24.3 × 25.6 mm (range 18—43 mm). 39.2% of stent grafts met the instructions for use criteria provided by the manufacturer.

Statistics

Results are given as mean (range). All calculations were performed using SPSS Statistics version 22 (IBM, Armonk, NY, USA). The Mann—Whitney *U* test was used to measure the difference in creatinine levels. $p < .05$ was considered statistically significant.

RESULTS

The mean operating time was 142 (66—308) minutes. The mean total radiation dose was 2,0433.4 (4934.5—59,366.9) μGym^2. The mean total radiation dose for CBCT was 7064.8 (3490.9—12,645.4) μGym^2. The mean total contrast dose was 28.1 (0—49.0) g iodine, including 8.9 g for CBCT (fixed injection). Owing to renal insufficiency, one patient did not receive any contrast, and the operation was completed with CO_2 imaging. All procedures were initiated percutaneously and groin closure included 35 bilateral fascia sutures, seven unilateral open femoral artery closures (planned) combined with contralateral fascia suture, and five cases of bilateral Perclose (Abbot Inc., Chicago, IL, USA). One patient received unilateral percutaneous closure and a contralateral fascia suture.

Intra-operative findings found on CA, CBCT, and FU CTA are shown in Table 1 and further described below.