Three-dimensional fusion computed tomography decreases radiation exposure, procedure time, and contrast use during fenestrated endovascular aortic repair

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Objective: **Endovascular surgery has revolutionized the treatment of aortic aneurysms; however, these improvements have come at the cost of increased radiation and contrast exposure, particularly for more complex procedures. Three-dimensional (3D) fusion computed tomography (CT) imaging is a new technology that may facilitate these repairs. The purpose of this analysis was to determine the effect of using intraoperative 3D fusion CT on the performance of fenestrated endovascular aortic repair (FEVAR).**

Methods: **Our institutional database was reviewed to identify patients undergoing branched or FEVAR. Patients treated using 3D fusion CT were compared with patients treated in the immediate 12-month period before implementation of this technology when procedures were performed in a standard hybrid operating room without CT fusion capabilities. Primary end points included patient radiation exposure (cumulated air kerma: mGy), fluoroscopy time (minutes), contrast usage (mL), and procedure time (minutes). Patients were grouped by the number of aortic graft fenestrations revascularized with a stent graft, and operative outcomes were compared.**

Results: **A total of 72 patients (41 before vs 31 after 3D fusion CT implementation) underwent FEVAR from September 2012 through March 2014. For two-vessel fenestrated endografts, there was a significant decrease in radiation exposure (3400 ± 1900 vs 1380 ± 520 mGy; $P = .001$), fluoroscopy time (63 ± 29 vs 41 ± 11 minutes; $P = .02$), and contrast usage (69 ± 16 vs 26 ± 8 mL; $P = .0002$) with intraoperative 3D fusion CT. Similarly, for combined three-vessel and four-vessel FEVAR, significantly decreased radiation exposure (5400 ± 2225 vs 2700 ± 1400 mGy; $P < .0001$), fluoroscopy time (89 ± 36 vs 64 ± 21 minutes; $P = .02$), contrast usage (90 ± 25 vs 39 ± 17 mL; $P < .0001$), and procedure time (330 ± 100 vs 230 ± 50 minutes; $P = .002$) was noted. Estimated blood loss was significantly less ($P < .0001$), and length of stay had a trend ($P = .07$) toward being lower for all patients in the 3D fusion CT group.**

Conclusions: **These results demonstrate that use of intraoperative 3D fusion CT imaging during FEVAR can significantly decrease radiation exposure, procedure time, and contrast usage, which may also decrease the overall physiologic impact of the repair. (J Vasc Surg 2015;61:309-16.)**

Fenestrated endovascular aortic repair (FEVAR) is becoming increasingly common and is now commercially available in the United States with recent Food and Drug Administration approval of a customized fenestrated device. With this technological advancement, there is an expected decrease in the physiologic insult to the patient compared with open repair[1-3]; however, this comes with increased radiation and contrast exposure risk during the procedures.[4] Fluoroscopy is an important radiation source in contemporary practice, and an increasing focus on the effects of cumulative radiation exposure to patients and providers is present in the literature.[4-14] Notably, a recent report demonstrated that FEVAR is one of the most radiation-intensive procedures that vascular specialists perform.[4]

The FEVAR radiation dose is related not only to the fluoroscopy time but also to the density of the abdomen and pelvis and the frequent obliquity that is necessary to visualize target vessels adequately.[13] In addition, these procedures often require large amounts of iodinated contrast, which may be partly responsible for the known decrement in renal function that can occur after FEVAR.[15,16] Importantly, advanced imaging techniques have been shown to decrease operative times and radiation exposure as well as mitigate the need for contrast usage during routine EVAR.[17,18]

Our institution has recently upgraded to a fixed-imaging unit capable of three-dimensional (3D) fusion computed tomography (CT), and we sought to evaluate how this technology has affected the conduct of FEVAR

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and whether it has afforded any demonstrable benefit with regard to radiation exposure and contrast usage.

METHODS

The University of Florida Institutional Review Board (FWA00005790) approved this study protocol (#201300781). A waiver of informed consent was granted because all collected data pre-existed in medical records and no study-related interventions or patient contact occurred. Therefore, the rights and welfare of these patients was not adversely affected.

Patient selection. A review of our institutional endovascular aortic database was performed for patients who underwent FEVAR before and after inauguration of a hybrid operating room capable of 3D fusion CT imaging. To mitigate the effect of the learning curve over time, patients treated using 3D fusion CT imaging were compared with patients treated in the immediate 12 months before the availability of the new hybrid unit. Specifically, the dates of collection included patients receiving FEVAR in the 3D fusion CT-capable room beginning in September 2013 vs those treated in the 365 days before.

A single surgeon (A.W.B.) at our institution began offering FEVAR in January 2010. We intentionally excluded the initial 68 cases, of which 48 (69%) were three-vessel or four-vessel fenestration procedures, spanning a 2.5-year period, to minimize the effect of the operative team learning curve on the results of this study. In addition, no significant operative team personnel or device implantation technique changes occurred during the study interval.

The method of target visceral vessel catheterization has been described previously and did not change significantly during the study period.[19] Patients were grouped by the number of fenestrations or branches revascularized (ie, excluding fenestrations or scallops that were not supported with a stent). Patients undergoing a two-vessel FEVAR were compared separately from three-vessel and four-vessel FEVAR patients, and three-vessel and four-vessel patients were grouped to increase numbers for comparison. Demographics, comorbidities, intraoperative characteristics (including adjuncts as defined by the Society for Vascular Surgery standards[20,21]), and postoperative outcomes were abstracted from our prospective database or the electronic medical record, or both, as needed. Comorbidities were defined according to reporting guidelines.[1]

Clinical practice. All patients were recovered in a dedicated cardiovascular intensive care unit. Patients were mobilized and given a normal diet on postoperative day 1 if there were no clinical concerns, such as neurologic, cardiopulmonary, gastrointestinal, hematologic, or renal system derangements. Thereafter, patients were transferred to the floor (unless on the spinal drain protocol), and all indwelling lines and catheters were removed if clinical recovery continued to be uneventful. Once patients tolerated a regular diet and received evaluation by physical therapy, they were discharged from the hospital. A restrictive transfusion protocol exists at our institution, and patients generally receive a transfusion only for a hemoglobin of <7 g/dL unless there is evidence of hypovolemic anemia or cardiac ischemia. The need for spinal drainage was determined by the operating surgeon. Spinal drain protocols did not change during the study interval and have been previously published.[22]

Equipment and procedural details. Patients undergoing FEVAR before the 3D-capable operating room (no-CT group) availability were treated in a hybrid operating room using a fixed imaging Infinix VC-i (Toshiba Medical Systems, Tokyo, Japan) ceiling-mounted, single-plane system. Fluoroscopy was generally performed at a low dose of 7.5 frames per second (fps), and digital subtraction angiography (DSA) was performed at 3 fps, unless an increased frame rate was necessary for improved imaging, in which case 6 fps was used. This system was routinely used in conjunction with intravascular ultrasound (IVUS) imaging using a Volcano catheter (Volcano Corp, San Diego, Calif). Before device delivery, IVUS imaging was used to determine branch vessel locations.

After device delivery, a flush catheter was used to perform DSA in the anterior-posterior and lateral projections to mark the branch vessel locations. Next, the device was deployed while the radiopaque fenestration/branch markers were triangulated against the DSA roadmap imaging. DSA imaging was performed intermittently to facilitate vessel catheterization and confirm successful access to the respective target vessels. DSA runs were also routinely used to perform individual completion runs for the branch vessels and a completion aortogram. Contrast was minimized by diluting it to one-third strength (Visipaque 320; GE Healthcare, Hertfordshire, United Kingdom) for hand-injection imaging and to one-half strength for completion imaging.

Use of the 3D fusion CT-capable hybrid operating room began in September 2013, which uses an Artis zee system (Siemens Medical Solutions USA, Inc, Malvern, Pa; http://usa.healthcare.siemens.com/angio/artis-zee/artis-zee). Of note, the radiology technicians for our dedicated vascular operating team underwent advanced imaging training through Siemens before our first procedure, which allowed a rather seamless introduction of this technology into our practice. This unit was also used at a low dose of 7.5 fps, and DSA was performed at 4 fps.

Before the procedure, the operating surgeon used the Leonardo workstation (Siemens AG, Forchheim, Germany) to process the preoperative CT arteriogram (CTA) by placing digital marks around the orifice of each branch vessel on the CTA (Fig 1). These marks were saved, and an intraoperative noncontrast abdominal CT was then performed before sterile preparation and draping, a process that takes no more than 2 or 3 minutes, which adds little to the overall operating room time.

The Artis zee system acquires (Dyna CT) images by rotating around the patient 200° and obtaining an array of equally spaced 2D x-ray projection images. For