Impact of Hybrid Rooms with Image Fusion on Radiation Exposure during Endovascular Aortic Repair

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WHAT THIS PAPER ADDS

Experience has shown that the routine use of fusion during endovascular aneurysm repair has significantly reduced the exposure of patients and operators to X-rays and contrast volume injection during complex repairs, without jeopardising the overall procedure workflow.

Objective: To evaluate exposure to radiation during endovascular aneurysm repair (EVAR) performed with intraoperative guidance by preoperative computed tomographic angiogram fusion.

Methods: All consecutive patients who underwent standard bifurcated (BIF) or thoracic (THO), and complex fenestrated (FEN) or branched (BR) EVAR were prospectively enrolled. Indirect dose–area product (DAP), fluoroscopy time (FT), and contrast medium volume were recorded. These data were compared with a previously published prospective EVAR cohort of 301 patients and to other literature. Direct DAP and peak skin dose were measured with radiochromic films. Results are expressed as median (interquartile range).

Results: From December 2012 to July 2013, 102 patients underwent standard (56.8%) or complex (43.2%) EVAR. The indirect DAP (Gy.cm^2) was as follows: BIF 12.2 (8.7–19.9); THO 26.0 (11.9–34.9); FEN 43.7 (24.7–57.5); and BR 47.4 (37.2–108.2). The FT (min) was as follows: BIF 10.6 (9.1–14.7); THO 8.9 (6.0–10.5); FEN 30.7 (20.2–40.5); and BR 39.5 (34.8–51.6). The contrast medium volume (mL) was as follows: BIF 59.0 (50.0–75.0); THO 80.0 (50.0–100.0); FEN 105.0 (70.0–136.0); and BR 120.0 (100.0–170.0). When compared with a previous cohort, there was a significant reduction in DAP during BIF, FEN, and BR procedures, and a significant reduction of iodinated contrast volume during FEN and BR procedures. There was also a significant reduction in DAP during BIF procedures when compared with the literature ($p < .01$). DAP measurement on radiochromic films was strongly correlated with indirect DAP values ($r^2 = .93$).

Conclusion: The exposure of patients and operators to radiation is significantly reduced by routine use of image fusion during standard and complex EVAR.

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INTRODUCTION

The evolution of device technology has allowed physicians to perform more and more complex minimally invasive aortic endovascular repairs. Imaging systems have also evolved to facilitate these challenging procedures. For example, fixed-room flat panel detectors have demonstrated strong imaging superiority over standard fluoroscopic two-dimensional (2D) fluoroscopy imaging systems (mobile C-arms), which are limited by overheating and image degradation, particularly when performing complex endovascular aneurysm repair (EVAR).[1] Hybrid rooms, combining an optimal open surgical environment and advanced imaging capabilities are currently replacing mobile C-arms in the operating room.

The latest hybrid rooms have advanced imaging applications, such as contrast-enhanced cone beam computed tomography (CBCT; three-dimensional [3D] images acquired through a C-arm rotation around the patient), and preoperative computed tomography angiography (CTA) image fusion with live fluoroscopy to provide a "3D roadmap". The latter facilitates endovascular navigation and increases the accuracy of endograft implantation.[2,3] Despite the current widespread use of these new imaging applications, little has been published on their impact on exposure to ionising radiation.[4–6]

Published evidence suggests that repeated injections of contrast medium contribute to the development of lifelong nephropathy.[7] The effects of radiation are cumulative and put patients at deterministic risk of radiation injuries after exposure.[8] Also, clinical staff regularly exposed to radiation during everyday fluoroscopy-directed procedures are

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exposed to an increased incidence of stochastic injuries.[8] Thus, in addition to sticking to the "as low as reasonably achievable" (ALARA) principle to reduce the dose of radiation during EVAR,[8–10] new imaging applications should also help reduce exposure to radiation and contrast medium injection.

The aims of this study were to evaluate the impact of image fusion in a new-generation hybrid room during aortic endografting on patients, the exposure of physicians to radiation, and the volume of contrast medium injected into patients.

METHODS

Demographics

During the study period, all consecutive patients treated electively in a hybrid room with standard or custom-made endografts for aortic aneurysms or dissections were prospectively enrolled. Preoperative high-resolution CTA scans were always performed to enable design of the endografts, and to perform the fusion 3D models. Emergency procedures or procedures conducted without image fusion were excluded. Endovascular repairs of arch aneurysms with branched endografts were also excluded. All procedures were carried out under general or locoregional anesthesia by experienced operators.

Equipment

Procedures were performed under fluoroscopic guidance in a hybrid room (Discovery IGS 730; GE Healthcare, Chalfont St Giles, UK) with a 30 × 30 cm flat panel detector. Low-dose settings were used by default at a frame rate of 7.5 frames/second. Minimisation of the detector to patient distance was performed automatically by the X-ray system throughout the procedure, using patient contouring with capacitive sensor technology. Additionally, the system is equipped with a 56-inch display monitor that reduces the need for magnification. Following the ALARA principle to reduce X-ray radiation,[8,9] staff constantly minimised fluoroscopy time, narrowed image detector fields to maximise collimation, used protection barriers, and optimised angulations.

Before each procedure, bone and aortic 3D models were reconstructed from the preoperative CTA scan on a workstation (Advantage Workstation; GE Healthcare) (Fig. 1), and sent to the X-ray system. In the setting of a good quality preoperative CT scan, this process was performed in less than 2 minutes. When no good quality arterial phase was available, an extra 2 minutes of 3D model editing were required. It was then fused with live fluoroscopy (Innova Vision/Heart Vision; GE Healthcare). Registration of this 3D preoperative model was performed using bone landmarks visible on two fluoroscopic orthogonal shots (anterior–posterior and lateral) of the spine (Fig. 2). This step also took approximately 2 minutes. During the procedure, this layout was used to centre the region of interest, and to adjust collimation, without the need for fluoroscopy. The position of the renal arteries was confirmed by a 7-cc contrast medium injection at 30 cc/second performed once the endograft was inserted in the aorta (Fig. 2E). If necessary, registration could be refined at any time during the procedure by the operator. Two types of contrast medium were used (Omnipaque 300 mg I/mL or Visipaque 320 mg I/mL in the setting of renal insufficiency; GE Healthcare).

Dose fundamentals

The air kerma (AK; measured in Gy) is the absorbed dose and is computed at the interventional reference point, defined as 15 cm from the system isocentre toward the anode, which is a good estimation of patient skin entrance position. It is well correlated with the peak skin dose (PSD; measured in Gy), which is defined as the highest dose delivered to any portion of the patient's skin, including backscattered radiation during a procedure, and was used to assess the risk of deterministic effects, such as skin injuries.[8] The dose–area product (DAP; measured in Gy.cm^2) is the product of the AK by the exposed area. The DAP cumulated all along the procedure is linked to the stochastic effect (i.e., the increased risk of cancer) and can be converted in a first approximation to the effective dose (ED), expressed in Sievert (Sv), using a conversion factor.[11] However, there is no consensus on this conversion factor;

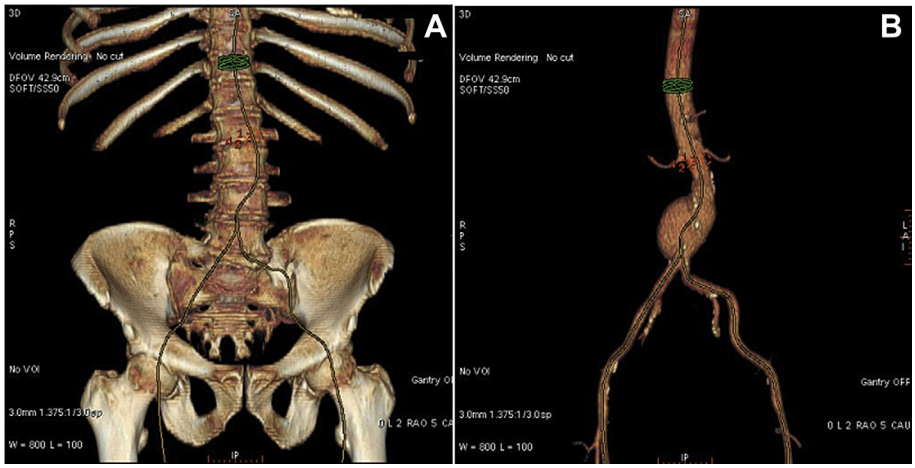

Figure 1. (A) A bone and (B) an aortic three-dimensional volume rendering model were reconstructed from the preoperative computed tomography angiography on a workstation (Advantage Workstation; GE Healthcare, Chalfont St Giles, UK).