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Risk of Radiation Exposure during Endovascular Aortic Repair

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WHAT THIS PAPER ADDS

- This paper reports radiation exposure in a large cohort of patients after endovascular repair of the thoracic and abdominal aorta. Techniques including computer software modelling are used to evaluate the amount of exposure and confirm that the patient can receive high doses of irradiation, especially after complex repairs. We suggest that efforts to minimise irradiation and closer follow up of patients that have had high exposures are required.

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ABSTRACT

Objective: Exposure to radiation doses above 2 Gray (Gy) can cause skin burns. There is also a lifetime cancer risk of $\approx$5.5% for every Sievert (Sv) of radiation. We assessed the radiation burden associated with endovascular treatment of the aorta.

Method: Thoracic (TEVAR), Infra-renal (IEVAR) and branched/fenestrated (BEVAR/FEVAR) endovascular aortic repairs were studied. The prospectively recorded dosimetric parameters included: fluoroscopy time and dose area product (DAP). Exposure films, placed underneath 10 patients intra-operatively, recorded skin dose and were used to calculate skin (Gy) and tissue (Sv) doses.

Results: The TEVAR cohort ($n = 232$) were younger ($p < 0.0001$) than BEVAR/FEVAR ($n = 53$) and IEVAR ($n = 630$). The median DAP was higher ($p = 0.004$) in the BEVAR/FEVAR group compared with IEVAR and TEVAR: 32,060 cGy cm^2 (17,207–213,322) vs 17,300 cGy cm^2 (10,940–33,4340) vs 19,440 cGy cm^2 (11,284–35,101), respectively. The equivalent skin doses were BEVAR/FEVAR: 1.3 Gy (0.71–8.75); IEVR: 0.71 Gy (0.44–13.7); TEVAR: 0.8 Gy (0.46–1.44). The whole body effective doses were BEVAR/FEVAR: 0.096 Sv (0.052–0.64); IEVR: 0.053 Sv (0.033–1.00); TEVAR: 0.058 Sv (0.034–0.11).

Conclusions: The radiation exposure during endovascular aortic surgery is relatively low for the majority but some patients are exposed to very high doses. Efforts to minimise intra-operative exposure and graft surveillance methods that do not use radiation may reduce the cumulative lifetime malignancy risk.

Introduction

Endovascular procedures play an increasingly important role in the treatment of vascular disease and have become the treatment of choice for the aorta. The radiation exposure involved can increase the morbidity associated with these treatments, by causing tissue damage and increasing the risk of malignancy.[1,2] Transient skin erythema may be seen within hours of exposure to peak radiation doses over 2 Gy, with higher exposures risking temporary epilation and tissue necrosis.[3,4] The biological effects of radiation on the whole body are measured in sieverts (Sv). With every Sv of radiation absorbed by the body there is a 5.5% detriment-weighted lifetime risk of induced cancer.[5] The long term risk associated with radiation exposure following endovascular aortic procedures, is often dismissed with the notion that the life expectancy of the typical patient is relatively short, coupled with the fact that there is a latent period of around 10 years for malignant transformation following radiation exposure. Improved standards of care, however, mean that life expectancy is increasing and significant radiation exposure in the younger patient is of particular concern.[6] Moreover,

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lifetime follow up with imaging modalities such as computed tomography (CT) can significantly add to the burden of radiation after the initial repair.

Intra-operative radiation exposure during endovascular procedures should be accurately quantified and attempts made to minimise this exposure should be a priority. We used validated techniques to quantify the amount of radiation to which patients were exposed during repairs of the thoracic and abdominal aorta.

Methods

Prospective data collected on all consecutive Infra-renal aortic repairs (IEVAR), thoracic endovascular aortic repairs (TEVAR) and branched/fenestrated endovascular repairs (BEVAR/FEVAR) between 2003 and 2010 was analysed retrospectively. All repairs were carried out in an interventional radiology suite. Indirect measurements recorded by the fluoroscopy equipment were Dose Area Product (DAP) and the fluoroscopy time. Dose Area Product is a crude estimate of radiation exposure which reflects the radiation dose and the area of tissue that has been irradiated and does not reflect the peak dose received by one particular area. We therefore made direct measurements of peak skin radiation exposure for a cohort of procedures and used software modelling to accurately quantify the amount of radiation absorbed by the body.

Quantification of peak skin exposure dose

A sheet of Gafchromic XR-RV2 film (International Specialty Products, New Jersey, USA) was exposed to a series of known radiation doses, ranging from 0.06 Gy to 4.0 Gy as seen in Fig. 1a. The film was scanned and analysed using the image analysis software Image J (National Institutes of Health, USA) to obtain a calibration curve Fig. 1b.

Prospective data was then collected using a cohort of 10 patients ($n = 9$ IEVAR, $n = 1$ BEVAR/FEVAR). A sheet of Gafchromic XR-RV2 film was placed under the patient during interventions in order to make a direct measure of the maximum intra-operative skin dose received (Fig. 2). The film was placed in a protective bag, underneath the mattress, before the patient was positioned on the operating table. At the end of each procedure the film was scanned and analysed as described above. The mean pixel value in the darkest region of the film was used to estimate the peak radiation dose absorbed by the skin using the calibration curve. The largest possible rectangular region of interest that fitted inside each uniformly irradiated area of the film was used. This area typically measured greater than 10 cm^2.

The ratio of measured skin dose to DAP was found for all 10 patients. The mean value of this ratio was applied to the DAP value recorded for each of the 915 procedures in order to obtain an estimate of the peak skin dose for every patient.

Whole body effective dose

The radiation dose absorbed by the body is non-uniform, with organs absorbing different quantities of radiation and they have different sensitivities to the radiation absorbed. In order to calculate the effective dose we used the PCXMC software (STUK Radiation and Nuclear Authority, Finland). The software takes into account variables including: X-ray examination details (parts of the body exposed, orientation, size of X-ray field) and the exposure itself (kV, DAP and X-ray tube details, including filtration, target angle and ripple). PCXMC uses Monte Carlo prediction and simulation methods to calculate the amount of energy deposited by the radiation passing through each organ. These organ doses are then multiplied by tissue weighting factors and added together to give the whole body effective dose.

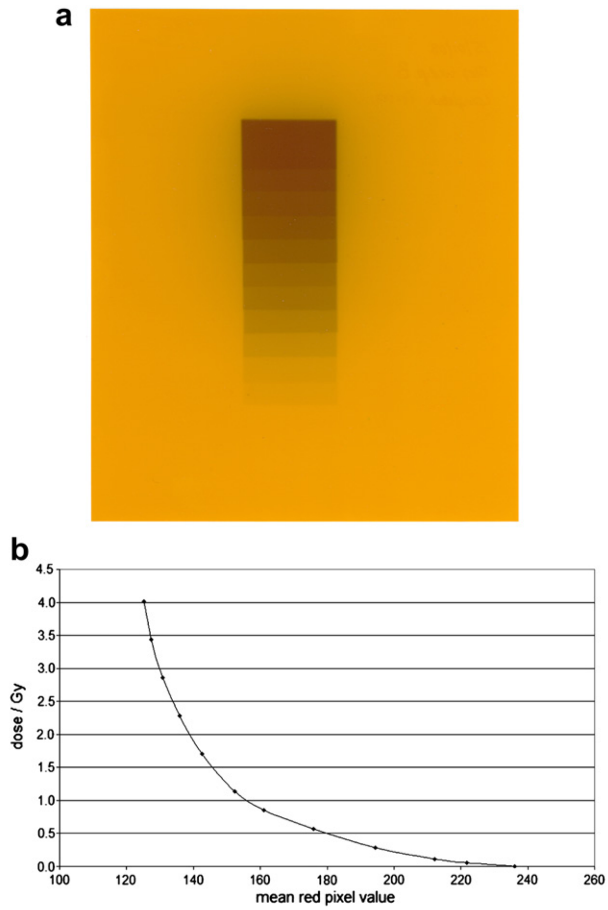

Figure 1. (a) A sheet of Gafchromic XR-RV2 film after exposure to known radiation doses. Darker colour signifies higher radiation exposure. (b) calibration curve obtained from plotting known exposure doses against mean pixel value.

Statistics

Spearman's rank test was used to assess the correlation between DAP and fluoroscopy time, and Chi Squared test to compare proportion of patients exceeding 2 Gy skin dose in each group. All other variables were compared using a Mann Whitney *T*-test. Variables were expressed as median with range or mean with standard deviation. *P* values of <0.05 were regarded as statistically significant.

Results

The TEVAR cohort ($n = 232$, age 71, 15–89), which included patients treated for aortic transection and dissections, were younger ($p < 0.0001$) than BEVAR/FEVAR ($n = 53$, median age 76, 58–85) and IEVAR ($n = 630$, median age 76, 37–93) Table 1.

The DAP was higher ($p = 0.004$) in the BEVAR/FEVAR group compared with IEVAR and TEVAR: 32,060 cGy cm^2 [17,207–213,322] vs 17,300 cGy cm^2 [10,940–334,340] vs 19,440 cGy cm^2 [11,284–35,101], respectively (Fig. 3).

The recorded DAP for the 10 patients for whom Gafchromic film was used was 14,351 cGy cm^2 (12,438–20,812). The equivalent skin dose was 0.6 Gy (0.5–0.85). The mean ratio of the directly