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Impact of patient anatomy on radiation dose during endovascular repair of abdominal aortic aneurysms

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ABSTRACT

INTRODUCTION: Endovascular aortic aneurysm repair (EVAR) has increasingly become the mainstream treatment of abdominal aortic aneurysms. However, because it requires ionising radiation, concerns about both patient and surgeon exposure have been raised.

METHODS: A retrospective analysis was conducted to evaluate all patients who underwent standard infra-renal endovascular aneurysm repair (EVAR) using aorto-bi-iliac endoprosthesis for infrarenal abdominal aortic aneurysms (AAA) from January 2018 to December 2022. All procedures were performed using the Ziehm Vision RFD mobile C-arm system (Ziehm Imaging, Nuremberg, Germany). The primary endpoint was to determine whether the Body Mass Index (BMI) was an independent predictor of intraoperative radiation exposure during EVAR procedures.

RESULTS: A total of 91 patients had recorded Dose Area Product (DAP) information. Of these, 76 had recorded height and weight for BMI calculation and were included in this study. The mean age was 73.5±8.3 years, and most patients were 72 male (94.7%). The mean BMI was 27.2±4.0 kg/m2, with 41% of patients classified as overweight and 22% as obese. Median DAP was 77.9 Gy.cm2 (inter-quartile range 51-123). DAP did not differ between sexes. A higher BMI category was associated with higher DAP values ($p = 0.008$). Higher DAP was also related to general anaesthesia ($p=0.002$) and intra-operative complications ($p = 0.031$). In multiple linear regression, BMI remained an independent predictor of higher DAP, with each additional kg/m2 of BMI increasing DAP by 5.15 Gy.cm2 ($p = 0.010$).

CONCLUSION: Higher BMI is associated with a higher radiation dose in standard EVAR procedures, which may be relevant when reducing both patients' and professionals' radiation exposure.

Keywords: Radiation dosage; Abdominal Aorta, Aneurysm; Endovascular; Obesity

INTRODUCTION

Endovascular aortic aneurysm repair (EVAR) has increasingly become the mainstream treatment of abdominal aortic aneurysm (AAA). However, since it requires the use of ionising radiation, concerns on both patient and surgeon exposure have been raised, both intra-operative and post-operative.[1,2]

Radiation effects are cumulative, increasing the risk of radiation injuries, both deterministic and stochastic, in patients and clinical staff exposed, and monitoring of radiation exposure is recommended.[3]

The "As Low as Reasonably Achievable" (ALARA) principle should be adhered to in all procedures and imaging utilising ionising radiation, which involves minimising the amount

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of radiation while maintaining diagnostic and procedural accuracy.[4]

Various factors, both procedural and patient-related, have been associated with radiation exposure, including procedure time, body mass index (BMI), fluoroscopy time, and aneurysm diameter.[5-7] It is essential for teams performing these procedures to understand the factors influencing radiation exposure and to be well-versed in methods to reduce it, as the literature reports a concerning lack of awareness of radiation.[8]

Multiple parameters can be used to evaluate radiation exposure, including fluoroscopy time, air kerma (AK), and dose area product (DAP). The European Society for Vascular Surgery (ESVS) guidelines recommend using dose parameters, such as AK and DAP, rather than fluoroscopy time, as these better objectively reflect radiation exposure.[3]

The aim of this study was to assess the impact of BMI on radiation exposure in standard infra-renal EVAR.

METHODS

A retrospective analysis was conducted to evaluate all patients who underwent EVAR for infrarenal AAAs from January 2018 to December 2022. Only patients who underwent standard infra-renal EVAR with aorto-bi-iliac endoprosthesis were included, excluding those with adjunct procedures, such as branch embolisation or iliac branch devices. Due to the retrospective nature of this study, informed consent was waived.

Patient demographics, including height and weight, were registered. BMI was calculated as weight (in kilograms) divided by height (in meters) squared and categorised as follows: BMI < 18.5 (underweight), BMI 18.5 - 24.9 (normal weight), BMI 25 - 29.9 (overweight) and BMI ≥ 30 (obesity). All procedures were performed using the Ziehm Vision RFD mobile C-arm system (Ziehm Imaging, Nuremberg, Germany). DAP, measured in Grays per cm2 (Gy.cm[2]), and fluoroscopy time, in minutes, were obtained from the intraoperative radiation dose monitoring system used during the EVAR procedures.

The primary endpoint was to determine whether BMI is an independent predictor of increased intraoperative radiation exposure during EVAR procedures. Data were presented as counts and percentages, mean ± standard deviation or median (interquartile range), as applicable. For univariable analysis, χ^2 or Fisher's test concerning qualitative data and Student's T-test for quantitative data were employed. For multivariable analysis, a multiple linear regression was performed. A two-tailed type I error rate of 0.05 was considered for statistical significance.

RESULTS

A total of 121 patients were initially included, of whom 91 had information on DAP. Of these, 76 had height and weight data for BMI calculation and were therefore included in this study. The mean age was 73.5 ± 8.3 years, and 72 were male (94.7%). The mean BMI was 27.2 ± 4.0 kg/m2, with 41% of patients overweight, followed by normal weight (36%) and obesity (22%). Median DAP was 77.9 Gy.cm2 (51-123). Median fluoroscopy time was 23.8 min (5.2 – 27.0). Demographic and procedural data are presented in Table 1.

Table 1. Demographics, comorbidities and procedural details of standard EVAR patients included in this study

Male – N (%)	72 (94.7)
Age (years) – mean ± SD	73.5 ± 8.3
Hypertension – N (%)	61 (80.3)
Smoking history – N (%)	43 (56.6)
Diabetes – N (%)	20 (26.3)
Coronary artery disease – N (%)	26 (34.2)
Cerebrovascular disease – N (%)	14 (18.4)
Implanted endograft	
Medtronic Endurant – N (%)	34 (44.7)
Gore Excluder – N (%)	30 (39.4)
Cook Zenith – N (%)	8 (10.5)
Artivion E-tegra – N (%)	2 (2.6)
Terumo Anaconda – N (%)	1 (1.3)
BMI	
< 18.5 (underweight) – N (%)	0 (0)
18.5 - 24.9 (normal weight) – N (%)	45 (36)
25 - 29.9 (overweight) – N (%)	55 (41)
≥ 30 (obesity) – N (%)	25 (22)
DAP (Gy.cm[2]) – median (IQR)	77.9 (51-123)
Fluoroscopy time (minutes) – median (IQR)	23.8 (5.2-27.0)
Procedure time (minutes) – mean ± SD	147 ± 67

BMI: Body mass index; **DAP:** Dose area product; **Gy:** Gray; **SD**: Standard Deviation; **IQR:** Interquartile Range.

DAP did not differ between sexes. A higher BMI category was associated with higher DAP values ($p = 0.008$). Higher DAP was also associated with general anaesthesia ($p = 0.002$) and intra-operative complications ($p = 0.031$; Table 2). Aneurysm diameter was not associated with increased DAP ($p = 0.086$). Radiation exposure also did not differ by stent graft type.

On multiple linear regression, BMI remained an independent variable for higher DAP, with each increase in kg.m[2] of BMI increasing DAP by 5.15 Gy.cm[2] ($p = 0.010$).

Table 2. Dose area product values in standard EVAR patients, according to patient and operative variables

Category	DAP (Gy.cm[2])	p value
Male – mean ± SD Female – mean ± SD	101 ± 75.7 60.0 ± 28.7	0.286
General anesthesia – mean ± SD Local/regional anesthesia – mean ± SD	148.9 ± 55.2 82.2 ± 55.2	0.012
Intra-operative complication – mean ± SD No intra-operative complication – mean ± SD	155.68 ± 105.5 86.12 ± 59.6	0.031
BMI 18.5-24.9 (normal weight) – mean ± SD BMI 25-29.9 (overweight) – mean ± SD BMI ≥ 30 (obesity) – mean ± SD	76.3 ± 41.5 93.2 ± 77.1 145.7±99.0	0.008

BMI: Body mass index; **DAP:** Dose area product; **Gy:** Gray; **SD:** Standard Deviation

DISCUSSION

Higher BMI was independently associated with higher radiation exposure after standard infra-renal EVAR in our cohort. This finding is consistent with published literature. Derwich et al. reported that BMI had a higher predictive value for radiation exposure than aortic and iliac anatomical characteristics.[9] Hertault et al., in a multicentric study using fusion imaging, found that BMI was associated with DAP, with a coefficient of 0.07 per kg/m[2]. Other variables associated with DAP were fluoroscopy time, the percentage of fluoroscopy time spent at more than 30° lateral and/or more than 15° cranio-caudal angulation, and the percentage of digital subtraction runs.[5] Maurel et al. reported increased DAP in obese patients (BMI>30).[7] Another study by Sailer et al. reported an association between the first operator radiation dose and patient weight in EVAR.[2] Mandigers et al. also found higher DAP being associated with higher BMI, with each unit increase in BMI increasing DAP by 7180 mGy/cm2[10] Jungi et al. reported higher DAP associated with higher BMI both in EVAR and TEVAR.[11] Schaefers et al. reported higher DAP with increasing BMI, but only with fixed-arm systems compared to mobile-arm systems.[12] BMI ≥ 25 was also found to be associated with increased DAP in a study by Majewska et al., as well as iliac tortuosity and short aneurysm neck.[13] Another study by Wilson-Stewart et al. reported a high correlation of both Air Kerma and DAP in EVAR procedures according to BMI.[14] Similar results have been reported in complex EVAR procedures.[15,16]

In obese patients, the X-ray beam must penetrate more tissue before reaching the image detector. Since the image intensifier has low light output, a feedback signal increases the radiation dose until sufficient penetration is achieved to produce a bright image.[17]

This study is limited by its single-centre, retrospective design and by the exclusive use of a mobile C-arm system. In our centre, only a minority of EVAR procedures are performed with a fixed-arm system and were therefore excluded from analysis. Other fluoroscopic factors, such as digital subtraction runs and the number of angles, were also not included in the analysis due to unavailability. Morphologic analysis was also not possible due to missing preoperative CT scans.

CONCLUSION

In conclusion, higher BMI is associated with a higher radiation dose in standard EVAR procedures, which may be relevant when reducing both patients' and professionals' radiation exposure.

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