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DOSES TO PATIENTS AND STAFF FROM ENDOVASCULAR TREATMENT OF ABDOMINAL AORTIC ANEURYSMS – PRELIMINARY RESULTS

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Abstract

Patient radiation doses received during endovascular treatment of abdominal aortic aneurysms (AAA) can be significant and give rise to both deterministic and stochastic effects. Recording of dose-area product (DAP), fluoroscopy time and number of exposures together with calculations of effective dose were performed for 8 patients. In addition, the entrance surface dose was measured for 3 of the patients. Typically, DAPs of 340 $Gycm^2$, fluoroscopy times of 30 minutes and 310 exposures were obtained together with maximum entrance surface doses of 1,8 Gy and effective doses of 50 mSv. Finger doses to the staff performing the procedure were in the order of a few hundred μSv. Conversion factors (effective dose/DAP) and (maximum entrance surface does/DAP) of $0{,}61 \cdot 10^{-2}$ $Gy/Gycm^2$ and 0,15 $mSv/Gycm^2$, were obtained respectively.

1. Introduction

Endovascular treatment of abdominal aortic aneurysms (AAA) has been carried out since the early 90ies, but is still experimentally. The aim is to increase the survival rate and improve the quality of life for the patients. The procedure reduces the surgical stress and there is minimal need for intensive care. The patient is early mobilised and is discharged from hospital the third day postoperatively. About 30-50% of the patients fulfil the physiological and anatomical criteria necessary to be considered as candidates for this new, minimally invasive treatment modality.

This endovascular procedure may give rise to significant patient doses, due to potentially long fluoroscopy times, frequently use of different magnification modes together with a large number of exposures, and are therefore associated with both deterministic and stochastic risks. High skin doses may result in deterministic effects such as erythema, epilation, desquamation, tissue necrosis or ulceration [1, 2]. Such radiation induced skin injuries have already been reported in the literature following percutaneous transluminal coronary angioplasty (PTCA) [2-4]. The severity of these effects can be quantified by the entrance surface dose (ESD), which can be estimated using, for example, thermoluminescent dosimeters (TLDs) [5]. The stochastic risks of carcinogenesis and genetic effects are quantified by the effective dose (ED), which may be obtained by Monte Carlo simulations on phantoms [6].

The vascular surgeons and interventional radiologists performing the procedure may receive large occupational doses, for instance to their hands, since they are working close to the patient not only during fluoroscopy but also during the exposures.

Because of potential high patient doses associated with endovascular treatment of AAA, dose monitoring is of great importance. The most common way of dose monitoring is the dose-area product (DAP). In this procedure, DAP may be difficult to relate to the maximum entrance surface dose (MESD) and in some extent also to ED, because the irradiated skin area is varying during the procedure. Relationships between the easily measured DAP to both MESD and ED would therefore be of great help in estimating the risks of both deterministic and stochastic effects associated with this treatment.

In the present study, doses to the patients and staff associated with endovascular treatment of AAA were examined as well as conversion factors between DAP to both MESD and ED were carried out.

2. Material and methods

Eight patients (seven men, one woman) having a mean age of 66 years (range 56-79) were treated for AAA (mean 55 mm, range 51-60 mm) with bifurcated stent-grafts (AneuRx, Medtronics, Inc, USA). In some of the cases, stent-graft extensions were used to seal a distal leakage or to secure the limbs near the origin of the internal iliac artery. All patients were included and evaluated according to the Eurostar Protocol[1].

All the stent-graft procedures were performed in a newly designed vascular and endovascular operating theatre having a special designed operating table (Koordinat O.R.) [7]. Beyond that, the theatre was fitted with all the facilities found in an ordinary angio-lab. The X-ray equipment used in this study was a Siemens Multistar Plus equipped with a ceiling mounted C-arm with a four-field (14/20/28/40 cm) image intensifier (Sirecon 40-4 HDR). The X-ray generator used was a Polydoros IS-A.

DAP was measured with a transmission ionisation chamber (DAP meter) (Diamentor, PTW, Freiburg, Germany) permanently attached to the collimator. For each patient the total DAP was separated into contributions from fluoroscopy and exposure. At present time, no information is available of the calibration procedure or the uncertainty in the DAP measurements.

TLDs (LiF:Mg,Ti, Harshaw TLD-100 chips) were used to measure ESD. The TLDs were calibrated free in air using the radiation quality ISO N-60 traceable to the measuring institute in Utrecht, the Netherlands[2] [8]. Background radiation was corrected for by means of 4 non-irradiated TLD controls. Overall uncertainty associated with TLD readings were estimated to be within ± 10%. Patient skin doses were obtained by placing 14 TLDs in the median plane at the patients back. The TLDs were placed with 2 cm spacing and centered at the level of crista. Finger doses to the staff performing the procedure were obtained by placing a sterilised TLD ring dosimeter on the middle phalanx of the middle finger bilaterally under the surgical gloves. All TLDs were read within one day after irradiation.

Rough estimates of the effective dose to the patients were obtained from the total DAP using the NRPB-R186 software [9]. This program uses an average adult patient of 70 kg mass and 174 cm height for its calculations. The abdominal PA projection with field size of 35 x 47 cm^2 were chosen for the effective dose calculations. The use of this projection will introduce an error to the estimated effective dose, since the field size usually used are smaller and the irradiated area of the skin varies during the procedure. The overall error is estimated to be within ±25%.

[1] Data registry center for stent-grafting in Europe. European Society for Vascular Surgery.
[2] TLD ring dosimeters used for measuring finger doses were calibrated free in air on a rod PMMA phantom, 1,9 cm in diameter.

3. Results

The endovascular procedure was completed for all patients and the second limb was attached without any problems. There was no 30-days mortality and no serious complications were observed. The use of one extension in patient 2, 5 and 8 and two extensions in the case of patient 1 and 7, matches the variations observed in DAPs, fluoroscopy times and number of exposures taken (Figure 1). Even though the fluoroscopy times were relatively long, typically 30 minutes, the exposures contributed mainly to the total DAP. A mean total DAP of 340 $Gycm^2$ and an average number of 310 exposures were obtained for these eight patients.

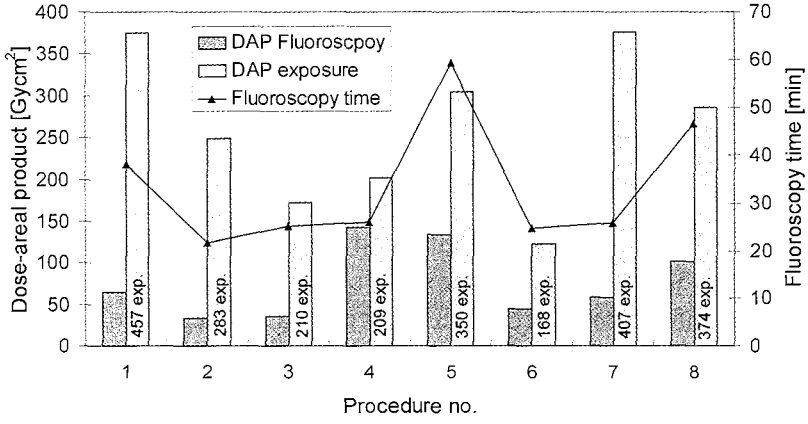

Figure 1. The contributions from fluoroscopy and exposure to the total DAP together with the fluoroscopy time and the number of exposures taken during endovascular treatment of AAA. At the present time, total uncertainty in DAP measurements are unknown

Skin dose distributions measured along the patients' back in the median plane are shown in Figure 2. Maximum skin doses in the range 1,3-2,3 Gy were obtained, matching the threshold dose for transient erythema for one of the patients. Maximum skin dose was generally localised somewhere between 6 cm cranialt and 10 cm caudalt from crista.

ED and MESD together with DAP to ED conversion factor (ED/DAP) and DAP to MESD conversion factor (MESD/DAP) for the procedure are given in Table I. Relatively high effective doses around 50 mSv were obtained. A mean ED/DAP conversion factor of 0,15 $mSv/Gycm^2$ and a mean MESD/DAP conversion factor of $0{,}61 \cdot 10^{-2}$ $Gy/Gycm^2$ were obtained for this procedure.

The finger doses to the surgeon and radiologists performing the endovascular procedure are shown in figure 3. The received finger doses, given a normal workload, were below the occupational dose limits of 500 mSv/year proposed by the ICRP [10], indicating a good working practice.

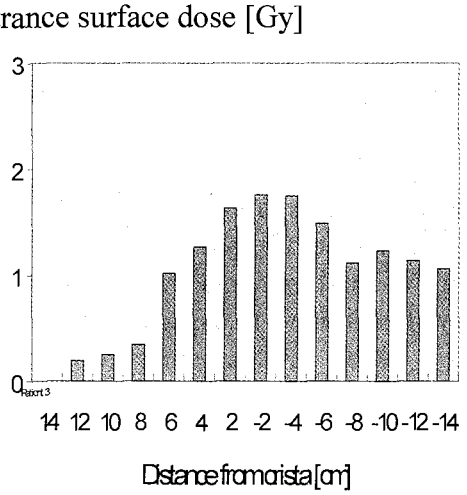

Figure 2. Skin dose distributions along the median plane of the patients back. Distances given in positive numbers and negative numbers are in the cranial and caudal direction from crista, respectively. The mean weight of the 3 patients was 83 kg, varying between 78-92 kg. Total uncertainty in the TLD readings was estimated to be within ± 10%

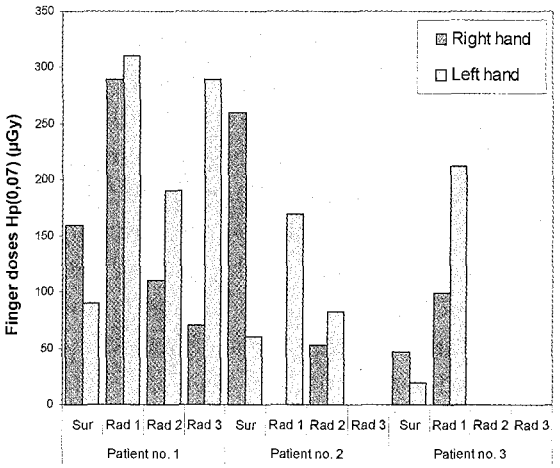

Figure 3. Finger doses received by the staff performing the endovascular treatment of AAA. Sur = surgeon, Rad = radiologist. Total uncertainty in the TLD readings is estimated to be within ± 10%

Table I. Mean values of total DAP, maximum entrance surface dose (MESD) and effective dose (ED) together with DAP to maximum entrance surface dose conversion factor (MESD/DAP) and DAP to effective dose conversion factor (ED/DAP) for the endovascular treatment procedure of AAA. Range is given in brackets

DAP [Gycm^2]	MESD [Gy]	ED [mSv]	MESD/DAP [Gy/Gycm^2]	ED/DAP [mSv/Gycm^2]
338 ± 32% (167-439)	1,79 ± 26% (1,35-2,27)	50 ± 34% (22-64)	$0{,}61 \cdot 10^{-2}$ ± 33% $(0{,}48\text{-}0{,}85) \cdot 10^{-2}$	0,15 ± 7% (0,13-0,17)

4. Discussion

Patients undergoing endovascular treatment of AAA are normally elderly and have as well, often, severe pulmonal and cardiovascular diseases. Total survival rate of these patients vary from 63-74%, depending on different publications [11]. Although the effective dose to the patient from this procedure is relatively high, 50 mSv, life expectancy and age distribution of the patients, indicate that deterministic skin injuries rather than stochastic risk of developing cancer are the effect to be considered. The main purpose with this study was therefore to establish a maximum advisable DAP to prevent skin damage such as transient erythema and temporary epilation, having threshold values of 2 Gy and 3 Gy, respectively. In obtaining a MESD/DAP conversion factor, TLDs were used to map the dose distribution along the patients back (Figure 2). To avoid missing the maximum skin dose it is of great importance to use many TLDs, especially in this procedure where magnification is used in combination with a moving primary beam irradiating different skin areas. Such use may result in an overlapping of exposed skin areas, which again can give high doses to small separated skin areas. By using

the MESD/DAP conversion factor of $0{,}61 \cdot 10^{-2}$ Gy/Gycm^2 (Table I), maximum advisable DAPs to avoid transient erythema and temporary epilation of 330 Gycm^2 and 490 Gycm^2 were obtained, respectively. By having a DAP meter available during the procedure, the operator can prevent skin injuries by not letting the total DAP exceed the limits for skin injuries. If additional exposure is required to finish the procedure, the operator may avoid the appearance of skin damage by changing the projection in such a way that the irradiation is spread over different skin areas. Of the eight patients studied in this work, five of them exceeded the DAP limit for transient erythema. Unfortunately, no follow-ups of these patients were performed to determine if transient erythema really did occur. No complications were associated with these eight procedures, but potentially much higher skin doses are believed to occur if complications had appeared. Therefore, the monitored DAP should always be registered in the patients case records and used in evaluating the need of individual patient follow-ups with respect to skin injuries.

Patients selected for endovascular treatment of AAA will receive additional doses from preoperative evaluations and frequently postoperative follow-up controls. CT-scan and angiography are performed preoperatively. At the ambulatory evaluation, CT-scan and plain X-ray of the stent-graft are performed 1, 3, 6 and 12 months postoperatively and each six months thereafter. In addition, 12 months postoperatively one angiography is performed. The total accumulated skin dose related to endovascular treatment of AAA, although not given as a single exposure, may have the potential for increasing the risk of developing skin injuries. The Norwegian Radiation Protection Authority has, in collaboration with Aker Hospital, University of Oslo, initiated a work where the total accumulated doses to the patiens undergoing this treatment are collected. The work will also include a close follow-up study of patients received doses above 3 Gy, with respect to induced skin injuries.

No dose measurements from endovascular treatment of AAA could be found in the literature, for comparison. It is believed that the variation in DAP values and skin doses are significant from hospital to hospital, since the results are depending on the practice of the persons whom performing the procedure and also of the weight of the treated patients. At this time, only limited data exists and more data should be collected before reference values and conclusions are drawn.

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