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FULL PAPER

Patient doses in endovascular and hybrid revascularization of the lower extremities

^{1,2}DEISLAVA D KOSTOVA-LEFTEROVA, PhD, ¹NADELIN N NIKOLOV, MD, PhD, ¹STEFAN S STANEV, MD and ¹BOYKA B STOYANOVA, MD

¹Clinic of Vascular Surgery, National Cardiology Hospital, Sofia, Bulgaria

²Medical College, Medical University – Pleven, Pleven, Bulgaria

Address correspondence to: Mrs Desislava D Kostova-Lefterova

E-mail: dessi.zvkl@gmail.com

Objective: Hybrid surgical methods such as remote endarterectomy and endovascular revascularization are fluoroscopy-guided procedures successfully replacing conventional open surgery for treatment of peripheral artery disease (PAD). The aim of this study was to: (1) evaluate the dose parameters describing exposure of patients undergoing endovascular or hybrid revascularization of the lower limb (below the inguinal ligament); (2) compare the data available in the literature with the evaluations of patients' dose values and related factors for patients undergoing such procedures; (3) examine the correlation of doses with certain parameters; (4) estimate the peak skin dose and assess the potential for radiation-induced skin injuries during the procedures.

Methods: Data for 259 patients were extracted retrospectively and analyzed. The procedures were grouped by type of intervention, vascular approach, and level of complexity. The analyses included the correlation of dose values with the operating team.

Results: The air kerma-area product (KAP) and fluoroscopy time (FT) values greatly varied depending on the procedure type but also among patients undergoing the same procedure. The type of vascular access has the largest impact on patients' doses. The KAP and FT values for brachial artery were: 347 Gy.cm² and FT: NA; for contralateral common femoral artery (CFA) approach: 207

Gy.cm² and 153 s; e.g. significantly higher than for ipsilateral CFA: 96 Gy.cm² and 78 s; for hybrid surgery: 77 Gy.cm² and 41 s; and for ipsilateral retrograde popliteal approach: 61 Gy.cm² and 53 s. The same tendency is observed for the peak skin dose (PSD) values: the highest are for brachial artery (2053 mGy) and contralateral CFA (1325 mGy) approach, followed by the ipsilateral CFA (748 mGy), hybrid surgery (649 mGy), and ipsilateral retrograde popliteal approach (566 mGy).

Conclusion: Registered dose values and FT for the different procedures do not exceed the International Atomic Energy Agency (IAEA) proposed trigger values for patients' follow-up for radiation-induced skin injuries. The type of vascular access has the highest negative impact on radiation dose levels and resultant KAP, PSD, and FT values. There is a significant increase of the dose values with increase of the number of inserted stents and the level of complexity. This should be considered in planning, especially for patients who undergo multiple diagnostic and therapeutic procedures.

Advances in knowledge: This study gives a systematic understanding for patient radiation exposure in endovascular and hybrid revascularization of the lower extremities, thus far absent in the literature.

INTRODUCTION

A wide range of fluoroscopy-guided procedures are performed to treat various types of pathological conditions. Some of these interventions are often performed in hybrid surgery rooms, where the fluoroscopy equipment is operated in the sterile environment of an operating theater room. In case the minimal invasive fluoroscopy-guided procedures are not adequate for treating the patient, in cases of more complex and acute procedures, these rooms become open surgery theaters, where vascular surgeons

perform open surgery. Hybrid surgery (mainly remote endarterectomy) and endovascular revascularization are two methods preferred to conventional open surgery for treatment of peripheral artery disease (PAD).¹ The prevalence of PAD varies between 4.3% and 29% depending on patient's age and it is now recognized as a global pandemic, affecting over 202 million people worldwide.^{2–4} Females with PAD present higher rates of functional decline and may have worse outcomes after invasive treatment for PAD compared to males.^{5–20} A longitudinal study of males and

females with PAD, shows that females are more likely to lose the ability to walk for 6 min continuously, are at a greater risk of mobility loss, and faster decline in walking velocity at 4 years of follow-up.⁶ Females with PAD who are subject of invasive treatment at advanced stages of the disease are more likely to require emergent vascular procedures and may be more likely to require amputation as first-line treatment compared to males.^{21–23} Known complications of endovascular procedures are local hematoma, distal embolization, arterial wall injury, restenosis/rethrombosis of the segment.¹ The hybrid surgery is combining the advantages of both conventional surgery and endovascular interventions.^{24,25} Possible complications, during and after remote endarterectomy, could be connected with rupture of the arterial wall, hematoma, infection, and early or late restenosis/rethrombosis.

Fluoroscopy-guided interventional procedures can result in relatively high radiation doses, especially for complex interventions. Radiation safety is an important issue for vascular specialists. Clinical dosimetry is a component of good patient management. Real-time dose monitoring allows the physician to achieve a good balance between the expected clinical benefit for the patient and the radiation risk of a prolonged procedure. The periodic analysis of the patient dose data provides valuable feedback for the purposes of the quality improvement and optimization of the process and the supervision and follow-up of individual patients. This can be important for the continuous management of high-dose procedures, in cases when the patient returns for further procedure.²

Patient radiation exposure is an issue that is often underestimated and underreported by some vascular surgeons.^{1,26,27} Patient doses depend on the characteristics of the X-ray system (image intensifier or flat panel characteristics, source-to-skin distance, collimation, magnification, Automatic exposure control (AEC) mode, and image acquisition rate etc.) and patient-related factors [age, weight, and body mass index (BMI)]. The dose rate is greatest at the skin area where the X-ray beam enters the patient. Patients with endovascular revascularization of the lower extremities are expected to be exposed to higher radiation doses.²⁶ The clinically important dose-related factors are: the type of vascular access and type of the procedure (*e.g.* balloon angioplasty, subintimal angioplasty, stent insertion).²⁶ Due to the high levels of exposure, a number of studies have reported patient doses in terms of air kerma-area product (KAP) for endovascular revascularization of the lower extremity. The reported KAP values are in the range 25–110 Gy.cm².^{26–32} Some fluoroscopically-guided procedures are associated with a risk of radiation injury to the skin.^{33–35} These injuries may be painful, disfiguring, and long-lasting.^{35,36} In general, the risk of patient injury as a result of radiation exposure during these procedures is low. The frequency of the actual incidence of deterministic skin effects for endovascular or hybrid revascularization of the lower extremity is still unknown.³⁵ Reduction of patient doses is crucial for minimizing the risk of radiation-induced tissue reactions. This requires extended dosimetric studies in endovascular procedures.

The aim of this study was to: (1) evaluate the dose parameters describing exposure of patients undergoing endovascular or

hybrid revascularization of the lower limb (below the inguinal ligament); (2) compare the data available in the literature with the evaluations of patients' dose values and related factors, for patients undergoing such procedures; (3) examine the correlation of doses with certain parameters; (4) estimate the peak skin dose and assess the potential for radiation-induced skin injuries during the procedures.

METHODS AND MATERIALS

The study was performed in a hybrid endovascular operating theater, equipped with a mobile C-arm fluoroscopy system with a 30 cm image intensifier (Radius R 12, Intermedical), and a carbon-fiber mobile table. The system is in operation since 2013.

All revascularizations were performed by three experienced and well-trained vascular surgeons.

Data for each procedure were obtained retrospectively using a standard form that included patient's age, height, weight, gender, exposure parameters, fluoroscopy technique, fluoroscopy time (FT), displayed KAP values, complexity of procedures. The degree of complexity was also routinely recorded as the local Hospital Information System mandatory requires it as a part of the operative protocol. The endovascular procedures performed were divided by degree of complexity in four groups. Complexity level (0) – percutaneous transluminal angioplasty (PTA) is marked when the target lesion is stenosis, resolved only with balloon angioplasty; degree (1) – PTA and stenting is marked when the result of the balloon angioplasty is unsatisfactory and the treated segment needs implantation of one or more stents for optimal effect. When the target lesion is in occlusion, a recanalization should be performed. Complexity level (2) – Recanalization and PTA; and (3) – Recanalization, PTA, and stenting is when different type of guide wires and catheters must be replaced/changed for optimal results from the first part of the procedure. The second part of the procedure includes balloon angioplasty and stent(s) implantation, if necessary. The main recorded and analyzed complexity parameters were the type of procedure, the type of vascular access, the treated segment, and the number and type of inserted stents.

Different aspects of endovascular fluoroscopy practice were assessed and compared for the three surgeons and their teams working in the room. The retrospective data collection included procedures performed between February 2014 and December 2015, a year after the teams started work in this theater room. The analyses were performed separately for each team. The correlation of the radiation dose with the skills, competence, experience, and training of operators was also studied.

KAP values were measured with a KAP meter built in the fluoroscopy system. During the quality control procedures of the C-arm unit operation, it has been verified that the accuracy of the KAP meter displayed values within $\pm 5\%$ for the clinically used tube voltages, dose rates, and field sizes.

The C-arm system provides also air kerma rate at the interventional reference point and cumulative air kerma. This dosimetry

information was not mandatory required in the local Hospital Information System as part of the operative protocol and there was no available data for the retrospective analysis. The X-ray equipment does not provide a real-time monitoring of the PSD and dosimetry equipment for routine measurements during the procedures was not available. PSD is the best indicator of the potential skin injury, but its estimation from KAP is problematic because of the movement of the X-ray tube around the patient during endovascular procedures thus irradiating different areas of the skin.^{37,38} The beam entrance port is varied by rotating the tube around the patient, because of the guidewire control, the control of the catheter, distal embolization control, drug-coated balloon, and stent placement in such a manner that oblique projections are rarely used during endovascular interventions.

PSD was estimated from a published dose conversion formula for interventional procedures as follows:³⁹

$$\text{PSD (mGy)} = 249 + 5.2 * \text{KAP (Gy.cm}^2\text{)}$$

This formula is approximation for most of the fluoroscopy units and it is not a precise replacement for the real peak skin dose, particularly below KAP of about 50 Gy.cm².³⁹

Statistical methods

Statistical analysis was performed with SPSS v.13.0. A descriptive analysis, analysis of variance and key independent samples tests were used. A *p*-value < 0.05 was considered significant.

RESULTS

A total number of 327 patients, between the age of 38 and 95, were included in the study. The mean value for patient's age was (66.8 ± 9.5) years. 239 (73.1 %) patients were male and 88 (26.9 %) patients were female. Endovascular procedures were performed in 189 (57.8 %) of the cases while hybrid procedures were performed in 70 (21.4 %) of the cases. A total of 68 (20.8 %) out of all 327 patients had their procedures with unknown vascular access and respectively were excluded from the cohort, thus leaving 259 procedures for further analysis.

Among the procedures included in the study, the most common were PTA, recanalization (intraluminal/subintimal), and stent insertion. The vascular access was ipsilateral common femoral artery (CFA) for procedures on popliteal and tibial arteries;

contralateral femoral artery for procedures on superficial femoral artery (SFA) and deep femoral artery (DFA); popliteal retrograde for ipsilateral SFA; brachial artery for both CFA and DFA.

The endovascular procedures were divided by degree of complexity in the following four groups: PTA (0); PTA and stenting (1); recanalization and PTA (2); recanalization, PTA, and stenting (3). The correlation between KAP values, the number of inserted stents, and the types of stents (Supera) was studied.

The following hybrid surgery procedures were included in the study: conventional CFA and/or DFA endarterectomy and remote endarterectomy of SFA with Vollmar ring stripper. During the study, the remote endarterectomy was always performed under fluoroscopy to verify presence of intimal flap. In case a flap was found, it was treated by a prolonged PTA or stent insertion. In the cases of acute thrombosis, due to stenosis of SFA, a thrombectomy was performed with Fogarty catheter, control angiography, and PTA or stenting of the stenosis.

The routine protocol used during most of the procedures was in automatic exposure mode including pulsed fluoroscopy with 7 frames per second and no magnification mode. Proper collimation was applied for all procedures. In some cases magnification mode of 15 cm (6 inch) or 10 cm (4 inch) was used for precise stent implantation. Digital subtraction angiography was used only for the final angiography documentation purposes. The results from the quality control measurements showed that the patient entrance surface air kerma rate was 16.85 mGy/min for the fluoroscopy mode with 7 frames/s. The KAP meter display was verified by additional measurements, and the accuracy of the displayed KAP values was found to be within 5%. The calibration protocol for the KAP meter included the table and the mattress in the X-ray beam. No additional correction has been applied to the presented KAP values.

The results for KAP and PSD values and FT for procedures with different vascular access, in terms of median value, range (minimal-maximal value) and interquartile range (IQR), are presented in Table 1. Table 2 shows the results of endovascular procedures of different complexity. The statistical analysis of the procedures' parameters and their correlation with the number of inserted stents per patient are presented in Table 3.

Table 1. Results for KAP, PSD, and FT for endovascular procedures with different vascular access

Vascular access	Group size: total number (% of all)	KAP, Gy.cm ² : median value, range (IQR value)	FT, s: median value, range (IQR value)	PSD, mGy: median value
Ipsilateral CFA	133 (51.3%)	96, 1.7–208 (100)	78, 21–337 (81)	748
Contralateral CFA	32 (12.4%)	207, 2.2–711 (218)	153, 14–340 (160)	1325
Brachial artery	6 (2.3%)	347, 32–836 (N/A)	N/A	2053
Ipsilateral PA (retrograde)	18 (6.9%)	61, 0.6–157 (110)	53, 18–89 (48)	566
Hybrid	70 (27%)	77, 11–144 (111)	41, 28–152 (69)	649

IQR is the interquartile range; CFA, common femoral artery; FT, fluoroscopy time; KAP, air kerma-area product; PSD, peak skin dose. PA, Popliteal Artery;

Table 2. The results for KAP, PSD, and FT for endovascular procedures of different degree of complexity

Degree of complexity	Group size: total number (% of all)	KAP, Gy.cm ² : median value, range (IQR value)	FT, s: median value, range (IQR value)	PSD, mGy: median value
(0) PTA	78 (41.3%)	67, 0.6–711 (83)	39, 14–162 (59)	597
(1) PTA and stenting	20 (10.6%)	78, 2.3–237 (93)	59, 26–150 (71)	655
(2) Recanalization and PTA	39 (20.6%)	75, 3.5–353 (102)	84, 42–263 (100)	639
(3) Recanalization, PTA, and stenting	52 (27.5%)	121, 3–160 (292)	110, 25–340 (142)	878

IQR is the interquartile range. FT, fluoroscopy time; KAP, air kerma-area product; PSD, peak skin dose; PTA, percutaneous transluminal angioplasty.

The KAP values for the procedures balloon angioplasty, PTA with stenting, recanalization with balloon angioplasty are in the range 67–75 Gy.cm². The values for the most complex procedures - recanalization (including subintimal), balloon angioplasty, and stent(s) insertion are significantly higher - 121 Gy.cm² ($p < 0.01$).

DISCUSSION

Statistical analysis of the data collected shows that the type of vascular access is the most important influence on the KAP and PSD values (Table 1). Statistical analysis of the available data concerning the KAP and FT values for brachial artery (Median: 347 Gy.cm²/ FT: NA; Range: 32–836 Gy.cm²/FT: NA) and contralateral (Median: 207 Gy.cm²/153 s; Range: 2.2–711 Gy.cm²/14–340 s; IQR: 218/160) CFA approach show that they are significantly higher than for ipsilateral CFA (Median: 96 Gy.cm²/78 s; Range: 1.7–208 Gy.cm²/21–337 s; IQR: 100/81), hybrid surgery (Median: 77 Gy.cm²/41 s; Range: 28–152 Gy.cm²/18–89 s; IQR: 111/69), and ipsilateral retrograde popliteal approach (Median: 61 Gy.cm²/53 s; Range: 0.6–157 Gy.cm²/18–89 s; IQR: 110/48) ($p < 0.01$). The same tendency is observed for the PSD values: they are highest for brachial artery (2053 mGy) and contralateral CFA (1325 mGy) approach, followed by the ipsilateral CFA (748 mGy), hybrid surgery (649 mGy), and ipsilateral retrograde popliteal approach (566 mGy). Such procedures include fluoroscopy of different areas of the thorax and abdomen for the purposes of successful CFA, DFA, and SFA manipulation where the X-ray beam goes through thicker tissues. A contralateral approach results in higher radiation doses to patients than other approaches because the aortoiliac bifurcation needs to be crossed and because of the extra pelvic FT needed to accomplish this. The contralateral CFA and brachial artery approaches do not exhibit any significant difference in their respective KAP values. The explanation is that for both of them the significant

part of the doses is achieved in the beginning of the procedure when an abdominal fluoroscopy is obtained to cross the aortic bifurcation. The KAP and PSD values for ipsilateral retrograde popliteal artery approach are significantly lower than other approaches, because the X-ray beam is crossing through the thinner tissues.

There is a significant variation in KAP and PSD values, up to factor of 100 for procedures with the same degree of complexity (Table 2). Dose values vary with a factor of up to 300 for procedures with the same vascular access and the same number of inserted stents. The KAP, PSD, and FT values increase significantly with the increase of the number of inserted stents ($p < 0.01$). There is a strong dependence between the KAP values and patient's weight and BMI index ($p = 0.003$ and $p = 0.002$ respectively). The use of Supera-Abbott stent system, which requires the use of magnification mode for accurate placement did not increase significantly the dose values ($p > 0.05$). There is a statistically significant correlation between the number of series and the patient's dose ($p = 0.005$ with 2.54 Gy.cm² per series).

For hybrid surgical procedures, the fluoroscopy is used only to control the remote endarterectomy, for intimal flap fixation (if needed) and then a final angiography is performed. As a result, the dose values and the FTs are reduced. Significantly higher KAP values are observed only for the most complex endovascular procedures.

Procedures for patients with a higher degree of complexity or higher number of inserted stents required the use of longer FTs. For example, for a patient of 80 kg (0 degree of complexity, 0 stents, ipsilateral CFA vascular access, Team 3), an FT of 162 s was registered and a total KAP of 5.3 Gy.cm², or for a 70 kg (3 degree of complexity – drug eluting balloon

Table 3. The results for KAP, PSD, and FT for endovascular procedures with different number of inserted stents per patient

Number of stents	Group size: total number (% of all)	KAP, Gy.cm ² : median value, range (IQR value)	FT, s: median value, range (IQR value)	PSD, mGy: median value
0 (PTA only)	170 (65.6%)	76, 0.6–129 (85)	79, 14–290 (73)	644
1	70 (27 %)	106, 1.3–160 (86)	64, 25–340 (88)	800
2	16 (6.2%)	161, 7.6–507 (361)	111, 39–325 (209)	1086
3	3 (1.2%)	366, 27–427 (N/A)	221, 105–337 (N/A)	2152

IQR is the interquartile range. FT, fluoroscopy time; KAP, air kerma-area product; PSD, peak skin dose; PTA, percutaneous transluminal angioplasty.

Table 4. Number of procedures and patient dose in terms of KAP for three surgical teams

	Team 1	%	Team 2	%	Team 3	%
	N of procedures		No of procedures		No of procedures	
^a >Median (KAP)	90	56 %	21	36 %	17	46 %
^b <=Median (KAP)	72	44 %	37	64 %	20	54 %
^c Total	162	100 %	58	100 %	37	100 %

KAP, air kerma-area product.

^aNumber/percentage of procedures with KAP values higher than the median value.

^bNumber/percentage of procedures with KAP values lower than the median value.

^cFor two of the procedures the team information is not available.

used, 0 stents, ipsilateral CFA vascular access, Team 3) patient these values were 290 s and 7.7 Gy.cm², while for an 86 kg (3 degree of complexity, 1 stent, ipsilateral CFA vascular access, Team 1) patient, they were 55 s and 80 Gy.cm². These examples

show that the KAP values do not always correlate well with patient weight or FT. Patient's weight is not usually expected to increase FT but it is expected to increase KAP as a result of the higher kV and mA values forced by the AEC system to achieve

Table 5. Comparison with published data on KAP and FT for endovascular procedures

Procedure/description	Reference	KAP (Gy.cm ²)	FT, s
Peripheral/ low. extr. interv., 0 compl.	This work	67	39
Peripheral/ low. extr. interv., 1 compl.	This work	78	59
Peripheral/ low. extr. interv., 2 compl.	This work	75	84
Peripheral/ low. extr. interv., 3 compl.	This work	121	110
Peripheral/ diagn. femoral	Steele et al ⁴¹	43	222
Peripheral/ diagn. low. extr. ang.	Vano et al ⁴²	67	–
Peripheral/ diagn. femoral ang., analog	Hoskins et al ⁴³	24	102
Peripheral/ diagn. femoral ang., digital	Hoskins et al ⁴³	74	138
Peripheral/ diagn. femoral art.	Thwaites ⁴⁴	26	144
Peripheral/ diagn. low. extr.: conv./dig.	Ruiz-Cruces et al ⁴⁵	28/58	324/336
Peripheral/ diagn. low. extr. ang., dig.	Ruiz-Cruces et al ⁴⁶	30	222
Peripheral/ diagn. low. extr. ang.	Williams ⁴⁷	77.9	–
Peripheral/ diagn. femoral ang.	McParland ⁴⁸	46.7	432
Peripheral/ diagn. low. extr. ang.	McParland ⁴⁸	79.8	450
Peripheral/ lower extr.: diagn./therap.	Bor et al ²⁸	14/18	60/132
Peripheral/ diagn. low. extr.	Kaufman et al ⁴⁹	20	–
Peripheral/ diagn. av. of two locations	Kicken et al ²⁹	46	282
Peripheral/ diagn. femoral ang.	Castellano et al ⁵⁰	13.1	–
Peripheral/ diagn. low. extr.	Gfirtner et al ⁵¹	45	270
Peripheral/ diagn. low. extr.	Mini et al ⁵²	16	144
Peripheral/ lower extr.: diagn./therap.	Zoetelief ³⁰	16/41	–
Peripheral/ low. extr. interventions	Struelens ³¹	71.85	–
Peripheral/ low. extr. interventions	Segal et al ⁵³	66.2	960
Peripheral/ low. extr. interventions	Majewska ²⁷	109.9	–
Peripheral/ low. extr. interventions	Bor et al ⁵⁴	58.2	–
Peripheral/ low. extr. interventions	Kicken et al ²⁹	52.9	–
Peripheral/ low. extr. interventions	McParland ⁴⁸	61.7	–

FT, fluoroscopy time; KAP, air kerma-area product.

a satisfactory image quality. Procedures of lower complexity require shorter time than others regardless of the patient weight.

The three vascular surgeons started their endovascular practice at the same time, in the year of installation of the C-arm. The results show that "Team 1" performed the highest number of procedures with the higher degree of complexity (Tables 2–4). There is a statistically significant correlation between the team of endovascular surgeons and the patient's dose, number of patients, and the categorizations that they treated ($p < 0.05$) (Table 4). 56% of all procedures performed by Team 1, 36% by Team 2, and 46% by Team 3 had dose values exceeding the median. Possible reason for the higher KAP values for Team 1 could be the more frequent use of the brachial approach or the contralateral CFA (Table 1). The most complicated procedures were performed by Team 1.

The dose values in terms of FT, KAP, and PSD for all procedures of different complexity do not exceed the proposed by the International Atomic Energy Agency (IAEA) trigger values, for follow-up of patients for radiation-induced skin injuries.⁴⁰ The results also show that the PSD values are below the dose threshold for radiation-induced erythema with only few exceptions. The PSD threshold for radiation-induced erythema was exceeded only for two of the recorded procedures, both of them performed on obese patients, weighting more than 120 kg, BMI >37.8. However, it should be reminded that these doses are received from a single procedure and if an additional procedure is required for the same patient, there is a risk of exceeding the dose threshold for erythema. In this study, additional procedure was required for 37 (14.28 %) of all 259 patients. Such results show that the cumulative air kerma should be recorded, stored, and archived in the patient records.

Table 5 presents the comparison of the results from the current study for the KAP values and FT after the therapeutic endovascular lower extremity interventions with some published studies that have assessed lower extremity interventions. Studies reporting diagnostic procedures are also shown in the comparison. The survey of the published data shows that radiation dose in purely diagnostic procedures is typically lower compared with procedures when an intervention is performed.^{28,42,45–47,50,54–56} As shown in Table 5, the reported radiation doses in lower extremity endovascular interventions from the current study are in line with previous studies.^{29–32,48,53,54}

All procedures were analyzed as endovascular revascularization performed in the area of the lower extremity. It is difficult to perform direct comparison with the published data because of the various anatomic locations for this type of procedures. The procedure-related details were not available in a large number of the publications. Previously reported radiation doses in lower extremity endovascular interventions are in the same range as the results from our survey.

The findings of this study indicate that the type of vascular access has the highest impact on radiation dose levels. The conclusion is based on small number of cases in a single center and warrants further investigation. However, all procedures were performed in the same room, by few operators, thus minimizing variability. There is also a significant increase in the dose values with the increase of the number of inserted stents and the level of complexity. In cases of long and complex occlusions, only a single long stent implantation has to be considered.²⁸ The results from the current study show that another important factor affecting radiation dose in a procedure is the operator, which is in compliance with findings from similar studies.⁵⁷

A limitation of the study is also the lack of information in picture archiving and communication system/radiology information system for the cumulative air kerma. The two cases in which patients' doses exceeded the IAEA recommended trigger levels for patients' follow-up and the finding that additional procedure was required for 14% of the patients resulted in an improvement of the future data recording in the department. The data for the cumulative air kerma values was included in the patient history records.

All results and conclusions for the PSD values are based on an approximation of the real peak skin dose, particularly below KAP of about 50 Gy.cm².³⁹ 91% of the received doses in the department during the survey are below the value of 50 Gy.cm².

CONCLUSIONS

Endovascular lower extremity interventions involve significant radiation dose, which should be considered in procedure planning, especially for patients who undergo multiple diagnostic and therapeutic studies.

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