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EXTREMITY AND EYE LENS DOSES IN INTERVENTIONAL RADIOLOGY AND CARDIOLOGY PROCEDURES: FIRST RESULTS OF THE ORAMED PROJECT

J. Domienik[1,*], M. Brodecki[1], E. Carinou[2], L. Donadille[3], J. Jankowski[1], C. Koukorava[2], S. Krim[4], D. Nikodemova[5], N. Ruiz-Lopez[6], M. Sans-Mercé[6], L. Struelens[4] and F. Vanhavere[4]
[1]Nofer Institute of Occupational Medicine, St Teresa 8, 91-348 Lodz, Poland
[2]Greek Atomic Energy Commission (GAEC), Patriarhou Grigoriou Neapoleos 7, Ag. Paraskevi 15310, Greece
[3]Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Av. de la Division Leclerc 31, Fontenay Aux Roses 92260, France
[4]Belgian Nuclear Research Centre (SCK•CEN), Boeretang 200, 2400 Mol, Belgium
[5]Slovak Medical University Faculty, Limbova 12, Bratislava 83303, Slovakia
[6]Institut de Radiophysique (IRA), Grand Pré 1, Lausanne 1007, Switzerland

*Corresponding author: jdom@imp.lodz.pl

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The main objective of WP1 of the ORAMED (Optimization of RAdiation protection for MEDical staff) project is to obtain a set of standardised data on extremity and eye lens doses for staff in interventional radiology (IR) and cardiology (IC) and to optimise staff protection. A coordinated measurement program in different hospitals in Europe will help towards this direction. This study aims at analysing the first results of the measurement campaign performed in IR and IC procedures in 34 European hospitals. The highest doses were found for pacemakers, renal angioplasties and embolisations. Left finger and wrist seem to receive the highest extremity doses, while the highest eye lens doses are measured during embolisations. Finally, it was concluded that it is difficult to find a general correlation between kerma area product and extremity or eye lens doses.

INTRODUCTION

Several factors influence the doses received by the physicians during interventional X-ray procedures. For this reason, even for the same type of procedure, a large variability in doses is observed. Depending on the irradiated area of the patient, physicians are usually required to stand close to both the X-ray tube (the primary radiation source) and the patient (the main source of scattered radiation). They may be exposed to high dose levels even when the kerma area product (KAP) values are relatively low since there are unshielded parts of the body, for example the hands which they are usually not protected. Moreover, there are cases where legs could be exposed to dose levels higher than the hands[(1)]. Finally, eye lens could also be considered a critical organ[(2)].

The state-of-the-art analysis performed within the FP6 CONRAD project stressed clearly the importance of eye lens and extremities dose assessments. A clear lack of systematic data was observed, so there was a further need for study in this field[(3, 4)].

This is one of the aims of the ORAMED project. In particular, WP1 of the project is devoted to extremity and eye lens doses in interventional radiology (IR) and cardiology (IC). The main objective is to evaluate the dose levels to the eye lens and extremities of medical staff, to explain their variability and, finally, to elaborate procedures allowing for better assessment and reduction of exposures. The main aim of the work presented below is to analyse the doses to the eye lens and extremities and to identify the most important parameters influencing them. To get a better insight into quite complicated interactions of relevant parameters affecting doses, the measurements were also accompanied with Monte Carlo simulations which are presented in another study (E. Carinou, submitted for publication).

MATERIALS AND METHODS

The data have been collected from 34 European hospitals and cover 682 procedures so far. The monitored procedures are cardiac angiographies (CA) and angioplasties (PTCA), pacemaker and defibrillator implantations (PM/ICD), radiofrequency ablations (RFA), angiographies and angioplasties of lower limbs (DSA PTA LL), carotids, brain (DSA PTA C&C) and reins (DSA PTA R), embolisations and endoscopic retrograde cholangiopancreatography procedures (ERCP). The selection was based on two main criteria: high frequency of the procedures and/or high KAP values. A unified measurement protocol has been used by all partners in order to have a common way of collecting and measuring data for all types of procedures. The following data are collected: the parameters of radiographic system, protective equipment used (lead table curtain, ceiling mounted screen, special cabin, lead glasses, etc.), physician position, field parameters and geometry details (like kV, mA, projection, etc.), fluoroscopy time, number of images acquired and KAP values. The doses are measured in terms of the operational quantity $H_p(0.07)$, which is recommended for measurements of doses to eye lens and extremities[(5)]. Eight TLDs are used for a single procedure. They are placed in selected anatomic regions: on both legs (5 cm below the lead apron), on both ring fingers and wrists (on palmar or dorsal side depending whether the X-ray tube is under or over the table, respectively) and, finally, one dosemeter in the region between eyes and one near the left or right eye depending on whether the X-ray tube is on the left or right side with respect to the physician. If the physician wears lead glasses, the TLDs are placed in such a way that they are not shielded by the glasses.

An intercomparison exercise had been performed before the measurements started in order to assure that all partners evaluate the $H_p(0.07)$ values in the same way even though they use their own TLDs (TLD-100H or MCP-N pellets) and calibration methods. For this purpose, TLDs were irradiated to ^{137}Cs and X-ray beams and coherence of results was checked between every partners. All the irradiations were performed on ISO slab phantom in reference[(6)] and realistic fields. For the reference fields, the $H_p(0.07)$ values have been determined by the irradiation laboratory (CEA-LNHB, France) with traceability to primary calibrations, while for the realistic fields, the reference values were obtained with the aid of Monte Carlo simulations. The reference values ranged from 6 to 8 mSv. The lower limits of detection and the uncertainties range from 0.006 to 0.120 mSv and from 6 to 12 %, respectively.

RESULTS

Doses for various procedures

Figure 1 shows the distribution of the median KAP values for various procedures. KAP varies from 40 to 271000 μGym^2 recorded during ERCP and embolisation procedures, respectively. In general, the highest values were recorded during general angiography procedures, whereas the lowest during PM/ICD and ERCP procedures. KAP values present large variability, even within the same type of procedure, which is mainly due to its sensitivity to the complexity of the particular procedure and the experience of the physician.

Figure 2 shows median doses measured during particular procedures. The highest doses are measured during PM, DSA PTA R and embolisations. For the other procedures, the doses are all below 0.080 mSv, while for the ERCPs the doses are much lower (below 0.025 mSv). Furthermore,

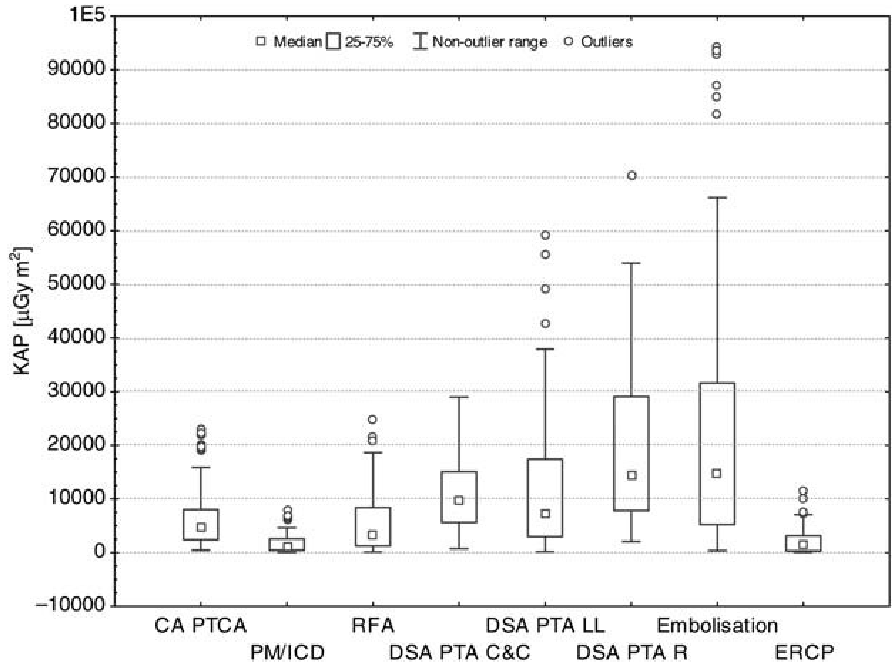

Figure 1. The median KAP values of the various procedures and the ranges are presented.

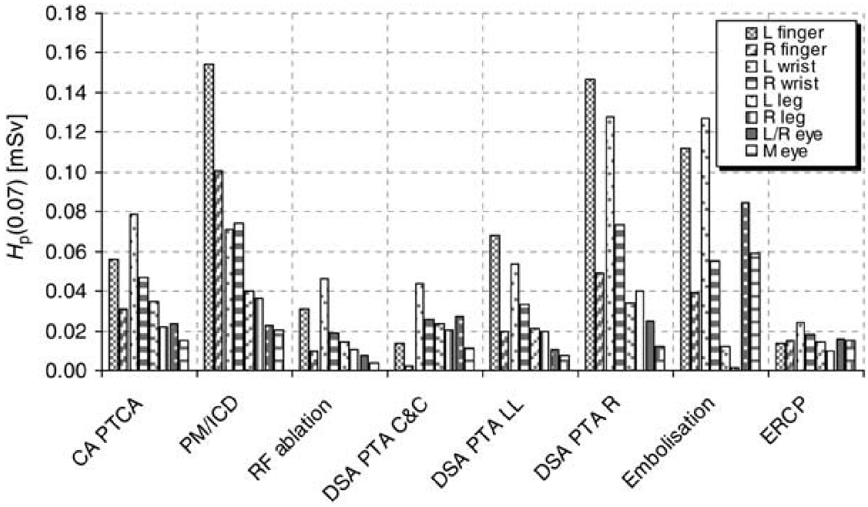

Figure 2. The median values of the $H_p(0.07)$ for various procedures in the different anatomic regions (L, left; R, right).

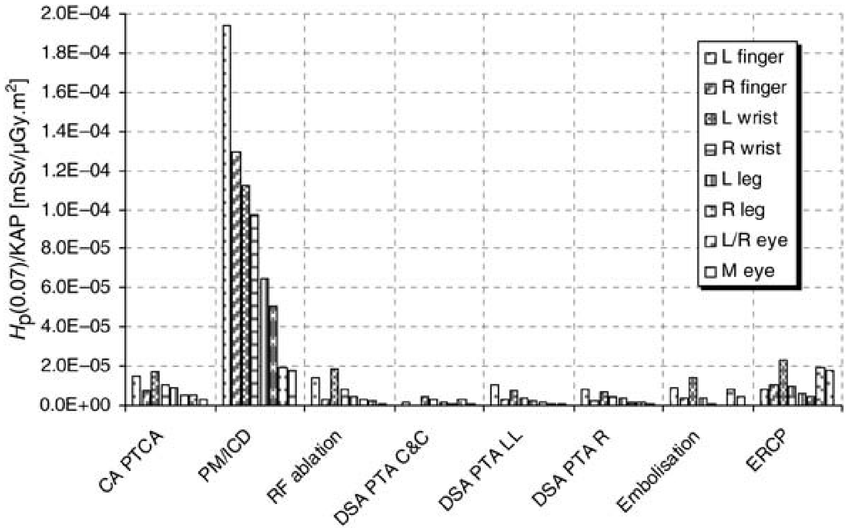

Figure 3. The median values of $H_p(0.07)$/KAP for various procedures in the different anatomic regions.

depending on the procedure, the parts of the body that receive the highest doses are left finger (PM/ICD, DSA PTA LL, DSA PTA R) and left wrist (CA PTCA, RFA, DSA PTA C&C, embolisations, ERCP).

The highest doses to eyes were measured during embolisations (0.085 mSv for left eye and 0.059 mSv for region between eyes). It should be noted that the effect of the use of lead glasses has not been evaluated yet. To compare procedures of different complexity, it was first normalised $H_p(0.07)$ to KAP for all separate procedures and then the median values of these ratios were calculated.

As shown in Figure 3, the highest $H_p(0.07)$ to KAP ratios are observed for PM/ICD procedures. During PM/ICD procedures, the physician stands close to the patient and to the X-ray tube.

Parameters influencing the doses

The most important parameters which were identified during measurements are physician's position with respect to the X-ray tube, the availability and use of additional protective equipment, tube configuration and individual practice (the operator leaving the room during cine, hands in the beam). To show the influence of these parameters on doses, some examples were selected. In the following data presentation, one parameter is changed at a time while the others are kept constant.

According to the author's protocol, the possible positions of the physician were identified: positions 3, 4, 5 and 7 (Figure 4). For positions 3, 4 and 5, the tube is on the left side of the physician, while for position 7 it is on the right side. In all cases, the left part of the physician's body is more exposed, even in the cases of PM/ICD (positions 3 and 4) and ERCP (position 7). For PM/ICD, this is because the field is almost in front of the physician and his left hand is always closer to the irradiated region. For ERCP, the left part of the physician is more irradiated due to the specific orientation of his body. The detailed data are presented in Table 1.

For CA PTCA procedures, two positions of the physician related to radial and femoral access were encountered: positions 4 and 5, respectively. In the case of radial access, the doses are generally higher than for the femoral access which is comparatively furtherer from the X-ray tube. However, this is not the case for the legs and for the region between eyes where doses are lower or similar.

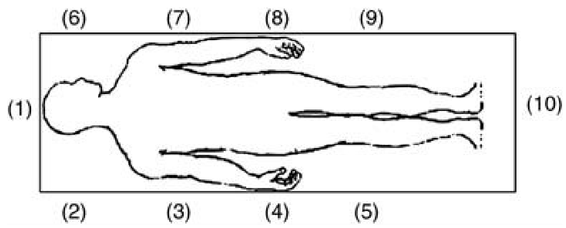

Figure 4. The possible positions of the medical staff with respect to the patient.

Figure 5 presents the comparison of doses received by the physician during CA PTCA procedures (femoral access) according to whether the protective devices were used (including both the lead curtain and ceiling mounted screen). In spite of the fact that other parameters have an influence, it is clear that the doses received by the physician are lower when the protection is used, especially for the legs. The degree of reduction depends on the anatomic region considered which needs further careful study.

As far as the position of the tube is concerned, the doses in ERCP procedures were analysed. For the over couch X-ray tube configuration doses to the eyes and hands are in general much higher (27 and 30 times, respectively) than for the under couch configuration, due to the backscatter radiation and the lack of additional protective equipment for the 'over couch' configuration. For the same reason, the doses to the legs are higher in the case of the under couch X-ray tube configuration than in the case of the over couch.

Table 1. Frequency of cases for which the maximum dose was registered in particular anatomic location.

Position no.	Procedures	Left side (%)				Right side (%)			
		Finger	Wrist	Leg	Eye	Finger	Wrist	Leg	Eye
3	CA PTCA, PM/ICD, RFA, DSA PTA LL, DSA PTA R, embolisations	31	31	12	2	8	9	7	–
4, 5	CA PTCA, RFA, DSA PTA C&C, DSA PTA LL	33	31	19	8	2	4	3	–
7	ERCP	13	11	33	26	0	17	0	–
	PM/ICD	47	15	5	–	27	2	3	–

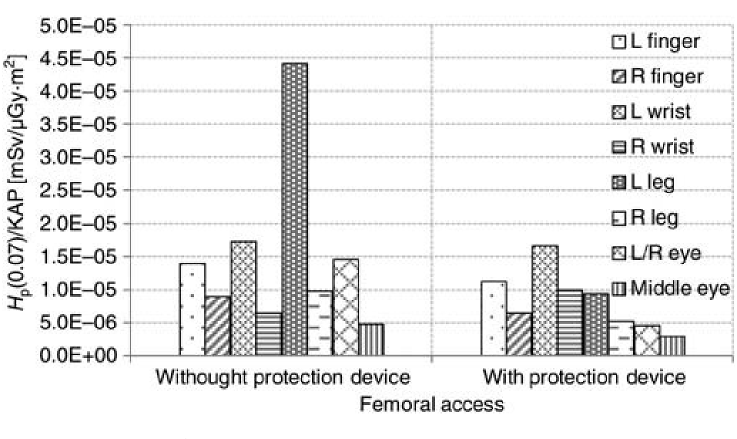

Figure 5. The median values of $H_p(0.07)$/KAP for the cases when the operator worked with or without protective device.

Table 2. The maximum doses recorded in specific anatomic region.

Region	L finger	R finger	L wrist	R wrist	L leg	R leg	L eye	M eye
Hp(0.07) [mSv]	7.3	1.3	3.6	1.3	7.8	2.8	4.1	3.2
Procedure	Embolisation	PM/ICD	Embolisation	ERCP	Embolisation	ERCP	ERCP	
Tube vs. table	Above	Below	Above	Above	Below	Below	Above	
Out during cine	No	No	No	No	No	No	No	
Protection	None	None	None	None	None	None	None	
KAP [μGym^2]	19 100	4 200	11 600	11 500	271 000	18 000	11 500	

At L eye, M eye and R wrist positions, the maximum was observed for the same procedure.

Moreover, the study showed that doses received by physicians depend heavily on individual practice and are strongly reduced if the physician leaves the room during cine mode. In some cases, doses to left finger and eye lens during embolisations were reduced almost four times while those on left wrist even five times. The same qualitative results hold true for DSA PTA LL and DSA PTA R. The conclusions on the influence of parameters mentioned above can be confirmed by the data included in Table 2 which presents the maximum doses measured in specific anatomic regions. The presented procedures are examples of situations when all unfavourable conditions are cumulated leading to high extremity doses.

DISCUSSION

The study reveals large number of parameters which should be considered significant when trying to analyse the extremity and eye lens doses of the physicians.

It is important to realise that some of these parameters are bound by financial restrictions or clinical quality reasons and cannot be easily changed. However, others are easily adjustable and improve significantly the protection of the physician. In view of the results of this study: the proper use of additional protective equipment and following good practices result in avoiding unnecessary exposure. So far, it seems that there is no evident correlation between the doses and the experience of the operator.

The large variability of doses can be attributed to different geometries and performances of the various X-ray systems, protective equipment, complexity of the medical procedures (fluoroscopy time, no of acquired images), work technique (position vs. X-ray tube, projections used, etc.) and physician's experience. The $H_p(0.07)/\text{KAP}$ ratio still depends on the work technique, unit performance and protective equipments. It is difficult to find correlation between the KAP values and the extremity and eye lens doses. Due to the reasons described above, there is also great difficulty in comparing the results in the various studies mentioned in the literature.

CONCLUSIONS

The analysis presented above clearly shows that further intensive work is needed in the field. The large number of factors influencing the final dose received by the physicians and their complicated interactions show that there is a need to collect a large number of measurement.

The different influencing parameters are intercorrelated so a multi-parameter analysis is needed. As far as the above-mentioned interactions are concerned, one expects the numerical simulations (also performed within WP1) to provide a powerful tool allowing for deeper insight into the problem.

The preliminary work reported in this paper is the first step towards an assessment methodology and it is expected to provide the basis for preparing the guidance for good practices in the field of extremity and eye lens radiation protection in IR.

In conclusion, the protocol used here, choice of parameters and TLDs' positions are considered to be good and provide the information necessary for detailed analysis which is now being performed.

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