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Staff eye lens and extremity exposure in interventional cardiology: Results of the ORAMED project

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ABSTRACT

Within the ORAMED project a coordinated measurement program for occupationally exposed medical staff was performed in different hospitals in Europe. The main objectives of ORAMED were to obtain a set of standardized data on doses for staff in interventional cardiology and radiology and to optimize staff protection. Doses were measured with thermoluminescent dosemeters on the ring finger and wrist of both hands, on legs and at the level of the eyes of the main operator performing interventional procedures. In this paper an overview of the doses per procedure measured during 646 interventional cardiology procedures is given for cardiac angiographies and angioplasties (CA/PTCA), radiofrequency ablations (RFA) and pacemaker and defibrillator implantations (PM/ICD). 31% of the monitored procedures were associated with no collective protective equipment, whereas 44% involved a ceiling screen and a table curtain. Although associated with the smallest air kerma – area product (KAP), PM/ICD procedures led to the highest doses. As expected, KAP and doses values exhibited a very large variability. The left side of the operator, most frequently the closest to the X-ray scattering region, was more exposed than his right side. An analysis of the effect of parameters influencing the doses, namely collective protective equipment, X-ray tube configuration and catheter access route, was performed on the doses normalized to KAP. Ceiling screen and table curtain were observed to reduce normalized doses by atmost a factor 4, much smaller than theoretical attenuation factors typical for such protections, i.e. from 10 to 100. This observation was understood as their inappropriate use by the operators and their non-optimized design. Configurations with tube above the patient led to higher normalized doses to the operator than tube below, but the effect of using a biplane X-ray suite was more complex to analyze. For CA/PTCA procedures, the upper part of the operator's body received higher normalized doses for radial than for femoral catheter access, by atmost a factor 5. This could be seen for cases with no collective protection. The eyes were observed to receive the maximum fraction of the annual dose limit almost as frequently as legs and hands, and clearly the most frequently, if the former 150 mSv and new 20 mSv recommended limits for the lens of the eye are considered, respectively.

1. Introduction

Cardiac diseases are still one of the most often causes of mortality in the human population. Interventional cardiology (IC) is a diagnostic or therapeutic technique in which cardiac chambers or coronary vessels are accessed by inserting catheters through blood vessels. Visualization and guidance of the devices inserted into the patient plus acquisition of additional high-quality images are done using X-ray imaging (fluoroscopy and radiography). Due to its advantages over surgery (low invasiveness, risk, cost etc.) the frequency of this technique has increased (Thom et al., 2006; Togni et al., 2004), so has the workload per physician (Vañó et al., 1998). The specific character of IC procedures results in inevitable

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[1] Deceased: this paper is dedicated to his memory.

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occupational exposure of the medical staff to ionizing radiation scattered from the patient. Significant radiation doses are received especially by unshielded body parts, primarily legs, arms, hands and eyes of the staff (Kim et al., 2008; Kim and Miller, 2009; Martin, 2009; Vanhavere et al., 2008).

These facts as well as the new technical developments, differences in the individual practices of the applied procedures and lack of systematic large-scale studies, have revealed the need to assess the actual doses received by the medical personnel, within the ORAMED (Optimization of radiation protection of the medical staff) project (see Koukorava et al., 2009 and Domienik et al., 2011 for preliminary results). Coordinated measurements were organized in 6 European countries in order to obtain a set of standardized data on extremity and eye lens doses for staff in IC. The main aim of the measurement campaign was to collect data on extremities and eye lenses doses received by the main operator. The results for IC are presented in this paper together with an analysis of the effect of parameters that influence the doses. Recommendations that could be formulated in order to optimize radiation protection measures are published elsewhere (Carinou et al., 2011).

2. Material and methods

2.1. Selected procedures

The following IC procedures were selected for the study: cardiac angiography (CA) and angioplasty (PTCA; percutaneous transluminal coronary angioplasty), radiofrequency ablation (RFA), and pacemaker (PM) and defibrillator implantations (ICD). A total of 646 procedures were measured in 56 hospitals from 6 European countries: Belgium, France, Greece, Poland, Slovakia and Switzerland. The detailed numbers per type of procedure are given in Table 1. In the following of the text CA/PTCA stands for either CA or PTCA procedure, i.e. both categories are considered together, and similarly for PM/ICD.

2.2. Measurement protocol

A unified measurement protocol was defined and used by all partners in order to have a common framework for collecting and measuring data for the different procedures. For each monitored procedure the following information was collected: operator and hospital identification, procedure type, access of the catheter, position of the operator with respect to the X-ray tube, personal (lead apron, thyroid collar, glasses, gloves) and collective (table lead curtain, ceiling suspended screen, mobile radiation protection cabin and wall) protective equipment, air kerma – area product (KAP) values and X-ray beam projection. KAP values were registered as indicated by the X-ray system, i.e. no additional calibration or correction factor was applied.

The doses were measured in terms of the dose equivalent $H_p(0.07)$, operational quantity recommended for dose measurements to eye lens, skin and extremities (ICRP, 1996; ICRU, 1998; ISO, 1999; EC, 2009). Eight thermoluminescent dosemeter (TLD) chips were attached to the main operator for a single procedure (see Fig. 1): four dosemeters were used to record the dose to the left (L) and right (R) hands, on the ring finger and wrist of both hands (L and R Finger, L and R Wrist positions, respectively) on palmar or dorsal sides depending on whether the tube was located below or above the patient couch, respectively; two dosemeters were placed on the legs (L and R Leg), few centimetres below the lead apron; finally two dosemeters were placed close to the eyes, one between them (on the forehead, M Eye), the other one next to the left or right eye (on the temple, L/R Eye) depending on whether the X-ray tube was on the left (the large majority of cases) or right side of the operator, respectively. If the operator wore lead glasses the TLDs were placed in such a way that they were not shielded by the glasses. The doses to the eyes were then assessed in absence of leaded glasses, thus overestimating the doses when leaded glasses were worn. Obviously, an additional suspended ceiling screen was or wasn't used, depending on the case. For some procedures, e.g. PM/ICD, because of sterility requirements it was not possible to monitor the hands; these cases corresponded to a small fraction of the overall collected data.

2.3. Dosemeters

The TLDs used were made of LiF:Mg,Cu,P and were calibrated against $H_p(0.07)$ in reference fields according to ISO standard (ISO, 1999). Because every partner used its own set of TLDs and calibration procedure, to assure that coherent results would be obtained an intercomparison exercise was organized before starting the measurements. Samples of TLDs were irradiated to ^{137}Cs beams and a more realistic X-ray field (70 kV, with a 4.5 mm Al and 0.2 mm Cu filtration) on an ISO slab phantom. They were read blindly by every partner using its own calibration procedure, and their response was checked against the conventionally true $H_p(0.07)$ value of the corresponding irradiation. Reference $H_p(0.07)$ values were equal to 8.0 and 6.6 mSv for ^{137}Cs and the 70 kV X-ray field, respectively. In the latter case the reference was calculated with Monte Carlo simulations. The range of the relative deviations of dosemeters' responses was within ±15% and it was considered acceptable. For every measurement in hospital the dosemeters worn by the monitored operator were accompanied by unused ones for subsequent background subtraction. The lower detection limit (LDL) of each partner was evaluated as twice the standard deviation calculated from the set of background dosemeters. LDLs ranged from 4 to 32 μSv, depending on the partner. Any dosemeter reading below the LDL was set equal to the LDL. Finally, for single measurements relative uncertainties were estimated in the range 13–20%, depending on the partner, taking into account the following components: calibration, repeatability, homogeneity, and dose, energy and angular responses.

Table 1
Numbers of procedures measured and associated descriptive statistics of the KAP distributions (minimum, 1st quartile, median, mean, 3rd quartile, maximum and standard deviation SD) for the IC procedures monitored in this work, and reviewed ranges of mean KAP and weighted mean KAP values (Kim et al., 2008 and references therein).

	N	KAP [Gy cm^2]								
		This work							Kim et al., 2008	
		Minimum	1st quartile	Median	3rd quartile	Maximum	Mean	SD	Range of mean KAP	Weighted mean[a]
CA/PTCA	261	4.3	21.4	44.4	75.0	419.7	63.3	67.0		
CA	80	4.3	12.4	18.9	34.3	198.8	32.2	38.3	13–130	41
PTCA	181	4.7	31.6	53.5	90.6	419.7	77.1	72.2	46–180	85
RFA	188	0.9	11.1	28.1	67.4	415.0	52.8	64.3	11–120	58
PM/ICD	197	0.1	4.2	12.2	39.2	509.8	36.8	69.9	5–15	12

[a] Mean of the mean KAPs of the reviewed studies, each one weighted by the number of monitored procedures.