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Staff and patient exposure to X-ray radiation during cardiac procedures

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Summary

Background: The aim of this study was to define and compare staff and patient doses during the most common types of cardiac procedures. The influence of operators' technique and quality of X-ray unit in use on doses received by the staff and patients was investigated.

Material/Methods: The study was conduced in two independent hemodynamic rooms (I and II). The doses to hand for medical staff (operators and nurses) were monitored. For hand dose assessment, ring thermoluminescent dosimeters were used. Regarding patient dosimetry, dose-area product was collected for selected procedures.

Results: The monthly hand doses ranged from 0.4 mSv to 41.2 mSv in room I and from 0.1 to 8.95 mSv in room II. On the basis of the above measurements, the annual doses were estimated. The maximum annual hand doses for the operator and for the nurse in room I were 232.8 mSv/year and 11.5 mSv/year and in room II – 29.8 mSv/year and 14.1mSv/year, respectively. Additionally, to compare the doses received by the particular medical operators, the doses were normalized to the total workload. Hand dose per procedure ranged from 109 to 614 μSv/procedure and were significantly larger in room I.

The typical DAP values (median) recorded for the CA and CA+PTCA procedures were 55Gycm2 and 171Gycm^2 in room I and 35Gycm^2 and 87Gycm^2 in the room II, respectively.

Conclusions: As a result of this survey, the impact of medical operator's experience as well as technique and quality of available X-ray units on doses received by staff and patients has been proven. On the basis of the above results, the special need for monitoring hand doses for medical staff, apart from the effective dose, has been recognized.

Key words: X-ray radiation • X-ray cardiac examination • received doses

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Background

The dynamic development of interventional cardiology in Poland has been observed during the last 11 years. According to the data published by the Working Group on Interventional Cardiology of the Polish Cardiac Society [1], in 2006 there were 86 running hemodynamic rooms (and 5 pediatric). The published data concerns 80 rooms equipped with 109 cardiac units. During the period 1996 – 2006, the number of Coronary Angiographies (CA) and Percutaneous Transluminar Coronary Angioplasty (PTCA) increased respectively from 23 571 to 135 828 and from 4986 to 69 820 (every year there is a substantial increase in the frequency). The substantial increase in frequency of cardiac procedures, together with the fact that doses to medical operators and patients due to cardiac procedures

are among the highest in diagnostic radiology, make the monitoring of the level of exposure important in radiation protection [2, 3].

The radiation risk resulting from exposure is widely attributed to the effective dose (as far as the stochastic effects are considered). In cardiac procedures, the effective doses to the medical operator are relatively low. However, they do not represent the total risk resulting from coronary angiography and PTCA examination. The probability of deterministic effect should be also taken into account. During cardiac procedures, some parts of the body of the medical operator (the organs and tissues most sensitive to ionizing radiation) are protected by a lead apron. The rest of the body like the eyes, neck or extremities might be, however, exposed to relatively high doses [2]. Especially hands of the radiologist might receive significant doses because they are localized close to the source of scattered radiation (patient) and sometimes they can even be exposed to primary radiation. In some situations, when number of procedures performed is large, this might result in exceeding occupational annual hand dose limit.

The radiation exposure of the patient is expressed by the means of patient mean surface dose which is usually measured with ionizing chamber indicating the area–exposure product. Many factors may influence the dose–area product values. These are mainly technique and experience of the medical operator, complexity of the procedure, patient's characteristic and the dosimetric factors set by the angiography unit in use. Long fluoroscopy time together with large number of acquired images might especially result in the doses to patient high enough to induce the deterministic effect [4, 5].

All the facts concerning cardiac procedures mentioned above result in publication of the reports by the bodies of experts from the field of radiation protection [6, 7, 8, 9] where the interventional procedures are defined as a "special practices" among other procedures involving high doses. They also emphasize the importance of quality assurance programs, which include quality control measurements of more and more sophisticated angiographic units, as well as patient and staff dose supervision.

Materials and methods

The survey was conduced in two hemodynamic rooms (I and II) in two centers. Three medical operators (A, B and C) and four nurses/technicians from room I and two medical operators (D and E) and four nurses/ technicians from room II were monitored. Monthly staff doses to hands (for medical operators, technicians and nurses) measured with one thermoluminescent dosemeter ring worn on the left hand were collected. The measured quantity was dose equivalent $H_p(0.07)$. The study on radiation doses received by the medical operator and on their workload was conduced. It is important to note that in room II both kinds of procedures: cardiac and interventional were performed. Thus, the reported doses to staff from room II include also doses resulting from interventional procedures.

The sample of patients was randomly selected in both centers. The data concerning fluoroscopy time, number of acquired images and dose–area product (DAP) were recorded for the most frequent cardiac procedures: diagnostic – CA and therapeutic – PTCA. The data for therapeutic procedures are the sums of CA and PTCA because PTCA is generally complementary to CA and it is difficult to separate these two procedures. The procedures were performed on two angiography units. Room I was equipped with a Philips Integris 3000 with a conventional image intensifier and frame acquisition rate 12.5 or 25 frames per second while room II was equipped with a GE Innova 2000 with a digital flat panel imaging detector and frame acquisition rate 15 or 30 frames per second. Both units have undercouch X ray tube configuration and work under automatic exposure control (AEC). The image intensifier input kerma rate measured with 1 mm copper filter and the entrance skin dose rate with backscatter included (measured with a 20 cm PMMA phantom at 90 cm source-to-image receptor distance, 65 cm source-to-skin distance) in room I were 0.43μGy/s and 56.3 mGy/min and in room II were 0.32 μGy/s and 18.6 mGy/min, respectively. The measurements were performed for maximum fields of view. In room I DAP meter type Doseguard were fitted to X ray tube retrospectively while in room II the DAP was calculated by algorithm from the exposure factors and collimator settings. The meters were calibrated from direct measurements of air kerma performed with the method employing TL dosimeters and from measurements of the X ray beam area using film [10]. Both quantities, dose and X ray beam area, were measured at the level of the table. The calibration factors obtained (which include also the effect of mattress and table attenuation) were 0.7 in room I and 0.6 in room II and they were used as correction factors to the corresponding read out DAP values.

Results

Table 1 presents the hand doses for the staff in room I and II. The maximum value of the hand dose registered during monthly dosimetric periods in room I is equal to 41.2 mSv, which is approximately 9 times higher than the same dose recorded in the second room II (4.7 mSv). Such a high dose received by the operator in room I might be caused by the large number of procedures performed during the specified dosimetric period. It should be noted that if this operator performed procedures with the same frequency during eleven subsequent dosimetric periods it would lead to the value close to the annual hand dose limit according to ICRP standards. On the other hand, the maximal effective doses estimated on the basis of routine dosimetric measurements are relatively low. In fact, the maximal annual dose value was 1.7 mSv.

Table 1. The hand doses in hemodynamic rooms I and II.

staff	hand doses	monthly hand doses [mSv]	maximal annual hand dose [mSv]
medical operator	room I	0.4 ÷ 41.2	232.8
	room II	0.1 ÷ 4.7	29.8
nurse	room I	0.4 ÷ 1.0	11.5
	room II	0.8 ÷ 2.0	14.1

Table 2. Reference levels in interventional cardiology.

Cardiac procedures	Parameters	The European Commission's Radiation Protection Research Program DIMOND III	The present study
CA	DAP [mGy*cm^2]	57	85
	FT [min]	6	5
	No. of frames	1270	801
PTCA	DAP [mGy*cm^2]	94	170
	FT [min]	16	12
	No. of frames	1355	-

In order to follow the recommendations of ICRP, we had to extrapolate the data to the period of one year. To this end, we replaced the missing data with mean values. This resulted in calculating the maximal annual hand dose.

As far as nurses are concerned, the maximal annual hand doses are comparable. However, for operators they differ almost by the factor 10. The same concerns the maximal hand doses (cf. Table 1).

The next step of the study was to compare the maximal doses normalized to the total number of procedures performed received by the operators and to select those operators whose practice may cause the unnecessary risk to themselves as well as to the patients. The data are presented in figure 1.

On the basis of data collected, it can be seen that the maximal hand dose per procedure for the medical operator falls within the range from 109 μSv/procedure to 614 μSv/procedure, which is comparable to the data reported in literature [11]. The obtained doses are significantly higher for the operators from room I. This might be caused by archiving higher number of frames during cardiac procedures CA and CA+PTCA (612 and 975, respectively) which is almost two times higher as compared with room II. This, in turn, might be the result of higher frame rates settings available in room I.

Regarding patient dosimetry, the dose-area product values for every procedure were considered. Typical values of DAP (calculated as median of the DAP distribution) measured at the level of the patient during one procedure are almost twice higher in room I than in room II. They equal 102 Gycm2 and 171 Gycm2 in room I and 35 Gycm2 and 87 Gycm2 in room II for the CA and CA+PTCA, respectively. This might be explained by differences in the number of archived frames, fluoroscopy time and values of dosimetric parameters of angiography units. In fact, in room I the recorded frames number and measured kerma rate at the input of image intensifier were higher when compared to those in room II, whereas the fluoroscopy time was similar.

In conclusion, this study allows to determine the local reference values for DAP, fluoroscopy and number of frames.

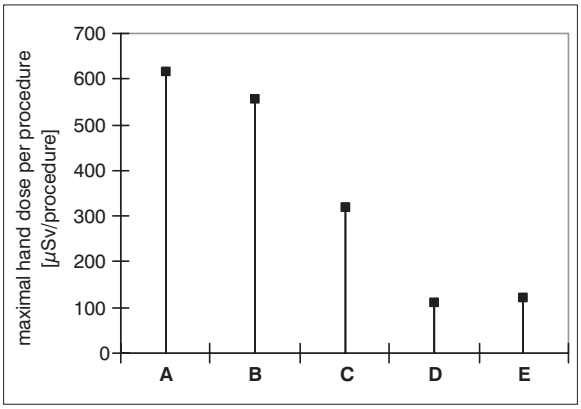

Figure 1. Maximal hand dose normalized to the number of procedures.

The results are presented in Table 2; except DAP values, the other data do not exceed the reference levels recommended by the DIMOND III European project.

Conclusions

The results obtained in the study reflect the fact that many factors of various origin might influence the doses received by the staff and patients during cardiac procedures. On the other hand, to some extent, this variety opens the possibility for optimizing the cardiac procedure by playing with factors we can modify. The study shows also that the doses to hand might be significant and that the danger of exceeding the dose limits might appear. Thus, the optimization of the procedures might be necessary. The differences in hand doses received by medical operators in both rooms were also observed. This calls for some explanation. To some extent, the differences are explained by dosimetric factors set by angiographic units or/and differences in technique and experience of radiologists. However, the human factor should be also taken into account. It is observed that some medical operators seem not to be aware of the importance of radiation protection and do not follow the instructions of the dosimeters usage. This might result in underestimation of doses.

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