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Occupational doses of medical staff and their relation to patient exposure incurred in coronary angiography and intervention

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HIGHLIGHTS

- Data on occupational and patient doses during interventional cardiology procedures were collected.
- Correlations were investigated and there is no linear correlation between kerma-area product and occupational doses.
- Annual eye lens doses were estimated.
- The results were compared with data published by another authors.

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ABSTRACT

Patient kerma–area product P_{KA}, cumulative kerma in the air K_{IRP}, fluoroscopic time t, personal dose equivalent (in terms of Hp(10), Hp(0.07) and Hp(3)) for most common interventional cardiology procedures were measured. P_{KA} and K_{IRP} measurements were used for patients and thermoluminescent dosimetry for the personnel. Dosemeters for personal doses measurements containing MCP-N (LiF: Mg, Cu, P) type thermoluminescence detectors (TLDs), were read out at the Institute of Nuclear Physics Polish Academy of Science (IFJ PAN) dosimetry service.

The patient and personal doses were similar to those reported by other authors. The mean values of total kerma–area product (P_{KA}) were 22.7 (7.3–50.9) Gy·cm^2 for coronary angiography (CA) and 43.1 (3.2–86.4) Gy·cm^2 for percutaneous coronary intervention (PCI). In general, doses received by the staff performing PCI procedures were found to be systematically higher than those after CA procedures, by some 30% or more. Within the medical team, operators always received the highest doses, followed by nurses and technicians. Maximum eye lens doses, skin doses and whole body doses were 165 μSv, 962 μSv and 30 μSv per procedure, respectively. Annual eye lens doses received by the operators, especially in PCI procedures, may well exceed the value of the recently recommended annual dose limit of 20 mSv and should be monitored.

No meaningful correlation could be established between occupational doses and patient exposure, however some degree of correlation was observed between values of dose to the eye lens and whole body dose.

1. Introduction

Evaluation of the relatively high doses received by medical staff and by patients undergoing interventional radiology and cardiology is of considerable interest as new techniques are being developed and the number of such procedures is rising. Such procedures, together with other radiodiagnostic imaging procedures (especially computer tomography – CT) significantly contribute to man-made exposures of the population. In interventional procedures, several factors, such as the specialisation of X-ray equipment, larger number of medical staff involved, high number of studies per day, or extended use of the X-ray beam, often required by the possible complexity of this type of study, lead to relatively high occupational exposures of members of the medical team, as well as to higher exposures of the patient, compared with other imaging procedures. Consequently, improved methods of evaluating individual doses received by medical staff and patients and their likely correlation need to be studied. Over the last decade or so, of main concern was

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the exposure of the operators who, within the cooperating team of supporting operators, nurses and technicians, typically receive the highest individual dose, including that to eye-lenses. Nowadays, diagnostic X-ray equipment delivers the kerma-area product (P_{KA}) which represents a measure of the dose received by the patient undergoing an interventional or diagnostic procedure. For legal reasons, all members of the medical team exposed to ionizing radiation must wear individual dosimetry badges, regularly read out by a dosimetry service.

Over the last years the number of interventional cardiology (IC) procedures has been rapidly increasing also in Poland, where 208 842 coronary angiography (CA) and 113 928 percutaneous coronary intervention (PCI) procedures were performed in 2012 (Dudek, 2013). Even for the same type of interventional procedure, occupational and patient exposures may vary considerably (Kim et al., 2008; Martin, 2009). Typically, exposure of the patient is primarily due to the primary X-ray beam, while that of the medical staff arises from radiation scattered from the patient and from elements of the X-ray equipment, thus being highly dependent on the position of the given staff member with respect to the patient couch. Thus, even if values of the kerma area product (P_{KA}) are low, members of the medical staff positioned close to the patient during fluoroscopy may receive high occupational doses, via unshielded parts of their bodies (e.g., their hands or eyes), unlike those who are further away. Thus, nurses and technicians usually receive doses lower than those received by the chief operator or accompanying operators.

While the risk of developing radiation-induced cancer from occupational exposures is that usually considered, other radiation-related risks have also been studied. In two independent reports (Ciraj-Bjelac et al., 2010; Vano et al., 2010), an increased relative risk of developing cataracts, a clouding or opacity of the eye which hinders vision, was observed in interventional cardiology personnel. The lens of the eye is one of the most radiosensitive tissues in the body, and its exposure to ionizing radiation may cause cataract formation (Brown, 1997).

Based on this epidemiological evidence, the International Commission of Radiological Protection (ICRP) has recently proposed that the occupational dose limit to the lens of the eye, averaged over 5 years, be reduced from 150 to 20 mSv, with 50 mSv may be exceeded in any one year (ICRP, 2012). This limit was approved and written down in the new EURATOM directive (Council Directive 2013/59, 2013). It was shown in some earlier studies (Carinou et al., 2014; Szumska et al., 2014) that this new limit may be exceeded by a significant percentage of interventional personnel.

There are several components to this study. Firstly we wished to evaluate the range of occupational exposures of medical personnel accrued within interventional cardiology procedures. The aim of this was also to determine if, and to what extent, actual exposure of the medical personnel, operators in particular, would exceed the recently proposed annual eye lens dose limits. We also sought to establish possible correlations between values of measured individual personnel exposures with patient P_{KA} values and finally between different measured occupational dose quantities to determine whether the accrued eye-lens exposures could be correlated with finger or whole-body exposures.

2. Materials and methods

2.1. CA and PCI procedures

Our study concerned three hospitals in Poland where interventional coronary angiography (CA) and percutaneous coronary intervention (PCI) are routinely performed. Coronary angiography is an X-ray examination of the coronary arteries, to show the occurrence and severity of stenosis or blockage of coronary arteries, to be followed by further treatment, such as percutaneous coronary intervention (PCI) if necessary. The aim of PCI is to dilate coronary arteries constricted by coronary artery disease, thus restoring arterial blood flow to the myocardium without open-heart surgery. In the PCI procedure, using a guidewire, a special catheter is inserted into the coronary artery and through the constricted area. The end of the catheter contains a tiny balloon which, when inflated, compresses the fatty tissue obstructing the artery thus dilating it to improve the blood flow through that coronary artery.

Typically, the interventional cardiology procedure is performed by three medical staff members: the operator-cardiologist, who is the principal operator, a nurse and a technician. Their usual positions are illustrated in Fig. 1. The operator usually places himself close to the chest of the patient (and to the X-ray beam) at the patient's right-hand side (Position 1), the nurse stands to the right of the operator (Position 2), and the technician usually controls equipment at end of the patient's couch (Position 3). The C-arm is usually upright-positioned, with the X-ray tube below the couch, to limit exposure of personnel by patient-scattered radiation. The personnel wear protective aprons and thyroid collars which shield the lower and upper parts of their bodies and arms from direct and scattered radiation. A ceiling suspended lead acrylic screen (typically of Pb equivalent of 0.50 mm) is used to reduce staff exposure from scattered radiation. When using these screens, it is important to remember that the source of radiation is scatter from the patient. The screen should be positioned directly between region be examined and operator. This kind of protection was used by the 71% of operators.

We analysed results obtained from 32 CA to 28 PCI procedures. In hospitals the procedures were performed on SIEMENS Artiss zee ceiling mounted system.

2.2. Evaluation of patient exposure

To assess the dose received by the patient, the kerma–area product (P_{KA}), expressed in $Gy \cdot cm^2$, cumulative air kerma at the Interventional Reference Point (K_{IRP}), expressed in Gy, and fluoroscopic time (t), expressed in min, were used. The value of the kerma-air product, P_{KA} is a measure of the total radiation energy entering the patient and has been recommended by the ICRU for monitoring the patient dose in fluoroscopy procedures, as an

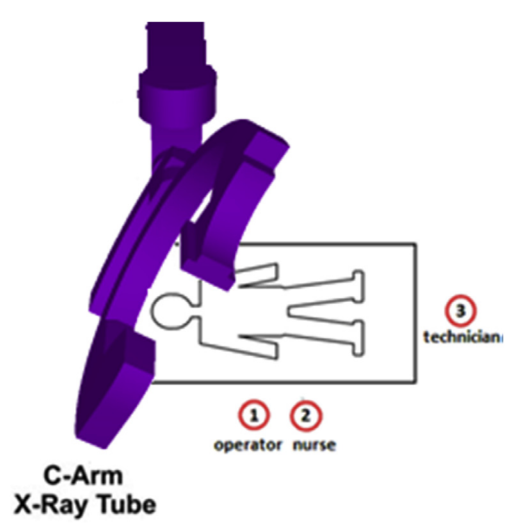

Fig. 1. Typical positions of medical staff during interventional procedures.