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Occupational doses to cardiologists performing fluoroscopically-guided procedures

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ABSTRACT

Interventional cardiologists (ICs) receive the largest radiation dose of any medical specialist working with X-ray techniques. The aim of present study has been to obtain dose estimates received by ICs during fluoroscopically-guided imaging and interventional procedures. TLDs in the form of badges, rings, and chips have been used, measuring $H_p(10)$ and $H_p(0.07)$ as appropriate. During the course of 41 coronary angiography (CAG) cases, 50 percutaneous coronary intervention (PCI) cases and 9 (CAG + PCI) procedures, cardiologist doses to the skin of the hands, upper neck area and to the eyes were assessed. Two-TLD badges were placed at the level of the Pb-composite collar exterior to the shielding, with a further two placed under and two more over the Pb-composite apron. Four chip-form TLDs were positioned above the eyebrows (two for the right- and two for the left eye), and two ring dosimeters were worn on the left and right hands. Cardiologist doses correlated with total fluoroscopy time over the five month period of the survey, the annual effective doses received by the body, eyes, hands and upper trunk area being estimated to be 8.0-, 10.7-, 24.3- and 10.2 mSv respectively, all well below the ICRP recommended equivalent dose limits, indicating well-controlled radiation protection practices.

1. Introduction

It is well known that interventional cardiologists (ICs) receive the largest radiation dose of any specialist physician working with medical X-ray techniques (Martin, 2011; Bor et al., 2009; ICRP Publication 113). Occupational doses representing personal dose equivalents in millisievert (mSv) for the whole-body are routinely measured. More challenging is the monitoring of other parts of the body, such as the extremities, upper neck area, and the eyes, all of which are more difficult to protect and all of which have their own dose limits, as detailed in and ICRP (2007). In particular, within the past few years the recommended occupational limit on eye dose has been reduced by 87%, from 150 mSv per year to 20 mSv per year (ICRP Publication 118). The reduction is well-supported by evidence for such need; see for examples Efstathopoulos (2016), citing data on the incidence of posterior lens opacities among staff involved in interventional procedures.

The interventional cardiology procedures of diagnostic coronary angiography (CAG), therapeutic percutaneous coronary intervention (PCI), percutaneous transluminal coronary angioplasty including stent deployment, peripheral angiography, percutaneous transluminal peripheral angioplasty (PTA) and electrophysiology are increasingly conducted in routine clinical practice (Singh et al., 2007). In the United Arab Emirates, the number of fluoroscopically-guided procedures have increased over the past few years, being one motivation in carrying out present research (Tsapaki et al., 2009). Such procedures involve the use of fluoroscopy i.e. x-rays taken over numbers of cine frames. Given the close proximity between cardiologist and patient in carrying-out interventional cardiac procedures (Bor et al., 2009), scattered radiation from the patient becomes a significant contributor to medical staff occupational dose. In some cases the primary beam itself also forms a potential source of exposure (ICRP, 2007), even with use of an under-couch x-ray tube (see Fig. 1).

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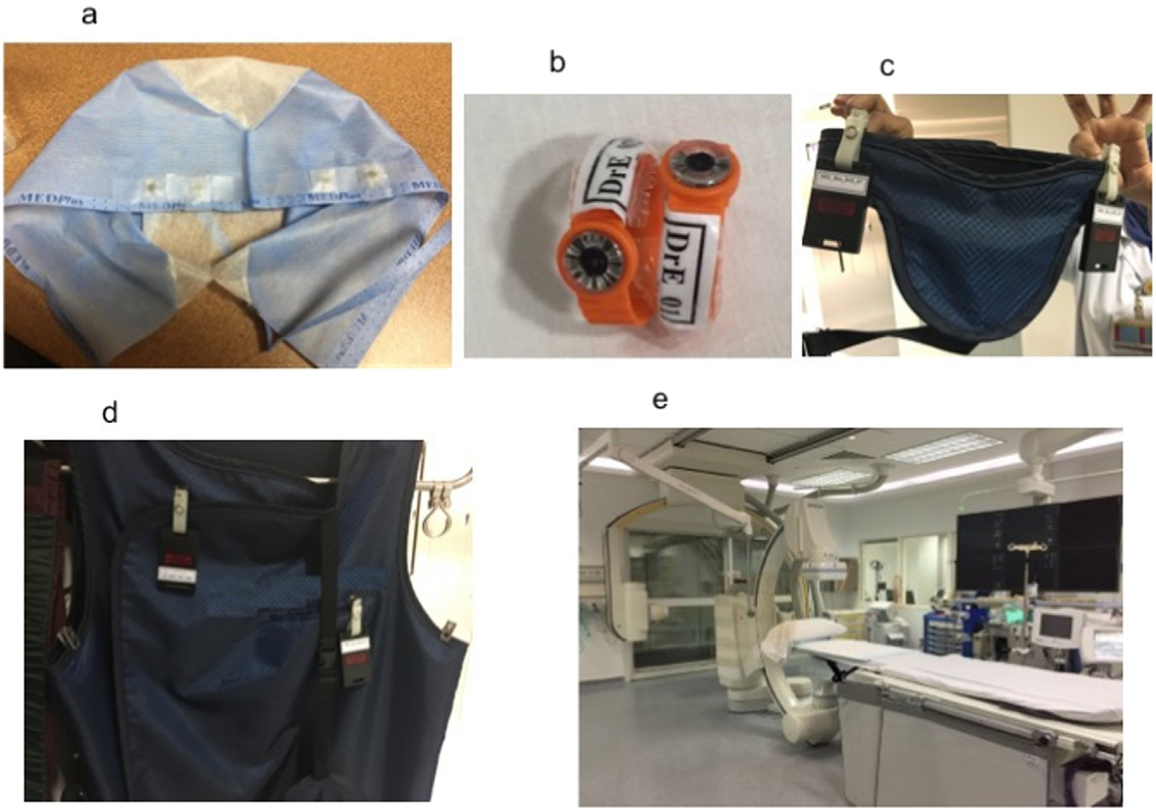

Fig. 1. (a) Eye dosimeters fixed to the head cap; (b) the ring dosimeters used for placement on the fingers; (c) the upper trunk dosimeters; (d) dosimeters placed over- and under a 0.35 mm Pb_{eq} apron; (e) the Cath lab within which the various interventional cardiac procedures were performed; note the C-arm under couch x-ray tube and over couch flat-panel detector.

In regard to the above, occupational doses become of particular interest in catheterization laboratories (typically abbreviated to Cath Labs), the latter being understood to be hospital/clinic examination rooms equipped so as to allow the imaging of cardiac blood vessels via minimal intervention procedures. In the Cath Lab, occupational doses to staff may indeed exceed annual limits recommended by the International Commission on Radiological Protection (ICRP) and may even induce deterministic effects as well as increasing the likelihood of stochastic radiation effects (ICRP, 2007; Vano, 2006), dependent on work-loads and practices. In association with this, the equivalent dose to the skin of the hands, to the upper neck area outside of the protective region afforded via use of a composite thyroid lead shield (collar) and the dose to the eyes may all be in the higher-tolerance range or even in excess of this, particularly in respect of eye doses. As such, close monitoring should be undertaken of hand doses, as well as that to the upper trunk area and to the eyes of the practitioners and other affected staff (Martin and Magee 2013; Bor et al., 2009; ICRP Publication 113). Herein, using several passive personal radiation dosimeters types, we have measured the effective dose to the skin of the hands, as well as the other indicated areas/sites. Further, we have also estimated the dose to the eyes based on a trunk-placed dosimeter. Similarly, the dose to the skin of the whole-body has been estimated, aided by use of key algorithms.

2. Material & methods

2.1. Dosimetry

$H_p(10)$ and $H_p(0.07)$ are two of the family of personal dose equivalents representing the probability of stochastic health effects. Specifically, $H_p(10)$ symbolizes the deep dose equivalent measured at a depth of 10 mm below a specified point of the body while $H_p(0.07)$ symbolizes the shallow dose equivalent at 0.07 mm below the surface of the body, also being referred to as the skin dose equivalent or surface dose equivalent. For a detailed discussion of these, see for instance Behrens et al. (2017) and also European Commission (2009). The chip thermoluminescent dosimeters (TLDs) that have been used herein for such evaluations are LiF:Mg, TI with a natural mix of Li isotopes (Thermo Fisher Scientific, UK), often referred to as TLD-100, a plastic capsule being added in measuring H_p (0.07) in order to allow study of eye dose. Behrens and Dietze (2010) have reported that in pure photon radiation fields dosimeters measuring $H_p(0.07)$ can be used for evaluation of eye dose, while if beta radiation contributes significantly to the dose then dosimeters measuring $H_p(3)$ are advisable (evaluating the deep dose equivalent at a depth of 3 mm below a specified point of the body, in this case the surface of the eye), $H_p(3)$ also being recommended by the IAEA (2013). The latter document also notes that dosimeters designed for $H_p(3)$ are not broadly available and for this reason in present work use has solely been made of appropriately calibrated $H_p(0.07)$ dosimeters for measurement of eye dose.

Four chip TLDs were placed just above the eyebrows on the forehead of cardiologists (two to the right eye and two to the left eye). Over the five-month period of the study, and in providing for consistent locational measurements of dose, all four TLDs were in each case adhered to a head cap that was then worn by the cardiologist over a sterilized new head cap. The arrangement, as shown in Fig. 1a, needed to be worn during each procedure. Two adjustable plastic ring dosimeter holders (Fig. 1b) were also used in providing for measurement of dose to the left and right hands. The dosimeter chips forming the dose sensitive medium were in each case fixed on to the rings. In addition, six TLD badges were used to measure $H_p(10)$ & $H_p(0.07)$, again of the type ^{7}Lif: Mg, TI (TLD-100), two being worn outside the thyroid collar in the neck area, one on the right-hand side and the other on the left (Fig. 1c), two were located over the apron at chest level and the remaining two were