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Review

Dosimetric studies of the eye lens using a new dosemeter – Surveys in interventional radiology departments

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HIGHLIGHTS

- An eye lens dosimeters was designed at the Personal Dosimetry Laboratory of CNEA.
- A successful dosimetric survey in two interventional departments was done.
- The annual effective dose and the annual eye lens dose are lower than the ICRP dose thresholds.
- In order to reduce doses actions should be promoted to maximize radiation protection.

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ABSTRACT

During interventional radiology (IR) and cardiology (IC) procedures, medical staff can receive high doses to their eye lenses. The Retrospective Evaluation of Lens Injuries and Dose study organized in Argentina in 2010 found incipient opacity in 50% of IC physicians and 41% of IC technicians/nurses. These results, added to the recommendations of the International Commission on Radiological Protection, which lowered their former occupational equivalent dose limit for the lens, led us to assess the eye lens dose, *H*p(3), during interventional procedures.

To this end, a new dosemeter was designed and calibrated at the National Atomic Energy Commission of Argentina to evaluate *H*p(3). Personal dose equivalent (*H*p(10)), and *H*p(3) were assessed for 3 months in two IC and IR departments. An Alderson phantom was used to simulate monthly exposures of five occupational staff members.

*H*p(3) and *H*p(10) were obtained monthly for 14 occupational staff members exposed to 121 IR and IC procedures. We concluded that the annual effective dose and *H*p(3) were lower than 0.3 and 10 mSv, respectively and the average cumulative *H*p(3) for working life was lower than 400 and 200 mSv for physicians and technicians/scrub nurse, respectively. An occupational annual dose constraint of 0.3 mSv was calculated.

1. Introduction

Interventional radiology (IR) and cardiology (IC) procedures involve physicians, nurses/scrub nurses and technicians exposed to X-ray scattered radiation coming especially from the patient and could accumulate high doses to the eye lenses. The growth in the use of fluoroscopy procedures and the few dosimetric controls carried out by the relevant national authorities have led to a growing concern of radiological risk. Optimization procedures that involve skill, training and radiation protection care of medical staff are relevant tools to reduce the staff dose.

The changes in the eye lenses after the exposure to ionizing radiation generally appear first in the posterior region of the lens with small dots which will form large opacities, called cataracts. Cataracts cause impaired vision and might lead to blindness (Merriam et al., 1972, 1983; Rehani et al., 2011).

The development of radiation-induced cataracts is considered a deterministic effect. For acute, fractionated and protracted exposures, the International Commission on Radiological Protection (ICRP) has lowered the recommendations for the lens dose limit from 5 Gy to 0.5 Gy because epidemiological studies have suggested that there are some tissue reaction effects where the manifestation

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appears very late. For chronic exposures, there is no indication that the limit is higher.

The ICRP recommends lowering the equivalent dose limit for the eye lenses of occupational staff to 20 mSv in a year, averaged over periods of 5 years, with no single-year dose exceeding 50 mSv (ICRP, 2012).

Other facts that motivated us to carry out this work, besides those already mentioned, were the results of Retrospective Evaluation of Lens Injuries and Dose (RELID) study. This is a multicenter study aimed to assess the incidence of radiation-induced cataracts in the population of interventional staff exposed to ionizing radiation in Argentina. The RELID was sponsored by the International Atomic Energy Agency (IAEA) and organized by the Latin American Society of Interventional Cardiology (SOLACI) in Buenos Aires during 2010. In Argentina the results showed that 41% of the technicians/nurses and 50% of the physicians included in this study and exposed to radiation showed incipient cataracts compared with less than 10% of the control group. Estimated cumulative eye doses ranged from 0.1 to 18.9 Sv (Vañó et al., 2013 and RELID).

Vañó et al. (2010) also presented a report from a RELID study which involved interventional medical staff from Bogotá (Colombia) and Montevideo (Uruguay). This report mentioned that 21% of the technicians/nurses and 38% of the physicians included in the study and exposed to radiation showed incipient cataracts compared with less than 12% of the control group. The report also mentioned that the cumulative median values of lens doses were 6.0 Sv for the cardiologists and 1.5 Sv for the associated medical staff. The average number of working years of the interventional cardiologists and nurses/technicians was 14 and 7 years respectively.

The goal of a safety program is to limit doses to specific organs and reduce the effective dose to decrease the radiation risk. The first step is the evaluation of the effective dose (E) and eye lens dose (Deye).

Although many studies have assessed the occupational doses from IR and IC procedures, it is important to emphasize the variability of their results. The differences in the staff exposure are due to: patient-medical staff distance, skill and training of medical staff, use of protective elements, beam orientation, procedure complexity, equipment performance, etc (Vanhavere et al., 2011).

Based on the results of different studies and DIMOND CA project, Padovani and Rodella (2001) summarized the effective doses received by cardiologists and nurses/technicians in IC procedures and reported that those received per procedure by the cardiologists ranged between 0.2 and 18.8 μSv and that those received by nurses and technicians ranged between 0.07 and 3.7 μSv.

Tsapaki et al. (2004) defined a preliminary occupational dose constraint value for cardiologists by calculating an annual effective dose of 0.6 mSv.

Concerning the cumulative eye lens doses, Jacob et al. (2012) carried out a retrospective assessment of interventional cardiologists related to the study for Occupational Cataracts and Lens Opacities in interventional Cardiology (O'CLOC). The results showed that the estimated cumulative eye lens doses of the 129 cardiologists studied, who had an average age of 51 years old and had worked for an average period of 22 years ranged from 25 mSv to 1600 mSv. These values indicate that according to the limit of 500 mSv, 25% of these cardiologists may develop early radiation-induced cataracts.

The aim of this work was to assess the risk of the occupational interventional community of Buenos Aires city and to analyze the protection radiation measures with the aim to optimize them and reduce the current dose. In Argentina, personal dosimetry laboratories do not provide eye dosemeters: thus, the dose is being estimated using whole-body dosemeters. For the purpose of this study, a new eye lens dosemeter was designed and calibrated at the National Atomic Energy Commission of Argentina (CNEA) and the values of the doses obtained were compared to the whole-body dose (WBD), personal dose equivalent ($Hp(10)$).

Fig. 1. Personal dosemeters to evaluate eye lens doses ($Hp(3)$).

The eye lens dose and the effective dose received by the physicians, scrub nurse and technicians of two of IC and IR departments were analyzed during a three-month period. A total of 14 medical staff members participated in this survey. An Alderson phantom belonging to the Nuclear Regulatory Authority was used to simulate the occupational staff. The values obtained were compared to those obtained by four of the physicians and one of the technicians.

2. Methodology

2.1. Personal dosimetry

2.1.1. Determination of the eye lens dose (Hp(3))

The most accurate method to monitor the $Hp(3)$ is to use a dosemeter with a 300 mg/cm^2 shield, recommended by the ICRP (2007) and the International Commission on Radiation Units (ICRU) 1993. In almost all cases, either the WBD or the skin dose $Hp(0.07)$ were used to monitor the $Hp(3)$. $Hp(0.07)$ has also been recommended by the European Commission (2009). A discussion of the adequate quantity to measure $Hp(3)$ is developed in Behrens and Dietze (2010) and Martin (2011).

Since this study involves interventional procedures where the exposures are nonuniform and would result in a higher dose to the eye lens than to the whole body, the lens dose should be measured with a dosemeter worn on the side of the head near the eye closest to the X-ray tube.

Thermoluminescent dosemeters (TLDs) for the eye lens (Fig. 1) were designed at the Personal Dosimetry Laboratory of the CNEA, following the recommendations of the Optimization of Radiation Protection of medical staff (ORAMED) project. Dosemeters used were LiF: Mg, Ti crystals TLD-700 of Harshaw (Ohio, USA), with chips of 3.2 mm × 3.2 mm × 0.89 mm. TLDs with a sensitivity lower than 2% were selected for this study. A special PMMA holder was designed to contain the TLDs (Vanhavere et al., 2012; Bilski et al., 2011). This holder was 40 mm long and 10 mm wide, in Fig. 1 that is the black PMMA. One end has a capsule with a chip inside, covered by a lid. The thickness of the PMMA in front of the TLD is equal to 3 mm of tissue.

After exposure, the TLDs of the interventional physicians and of the scrub nurse/technicians were read out in the Harshaw Model 3500, Thermo Scientific reader. The detection limit dose was of 0.1 mSv and the reading uncertainty of 10% with a coverage factor $k = 2$.

2.1.2. Calibration of the eye lens dosemeters at the CNEA

The TLDs were calibrated at the Secondary Standard Dosimetry Laboratory (SSDL) of the CNEA in terms of $Hp(10)$ and $Hp(3)$ in a W80 ISO 4037-1 quality, effective energy 57 keV (ISO, 1996) (Fig. 2),