# Estimation of eye lens dose for nurses in interventional cardiology using Monte Carlo simulations

Predrag Božović, Olivera Ciraj-Bjelac, Danijela Aranđić and Sandra Ćeklić

***Abstract* — Nursing staff involved in interventional cardiology is considerably exposed to ionizing radiation given their operating positions during procedures and placement of structural shielding. Since placing and wearing eye lens dosimeter is encumbering for staff, Monte Carlo simulation provide us with easy way to get indication on what doses to the eye lens are. Eye lens doses were estimated for three X-ray tube projections (PA, LAO and RAO) and tube voltages ranging from 80 kV to 110 kV with different protective equipment setups. Simulations were carried out using MCNPX code.**

***Index Terms* — Eye lens dose, Interventional cardiology, MCNPX**

## I. Introduction

The use of X-rays for interventional procedures has increased in recent years, and with the prolonged exposure times during these procedures, the radiation dose to the workers is significantly higher than doses for workers in diagnostic procedures. Because of that, there is need for adequate protection of workers in interventional radiology from ionizing radiation. Parameters that affect dose to the workers beside the number of procedures and exposure time in single procedure can be also the geometry, collimation, the distance of the image intensifier, distribution of scatter radiation (projection of x-ray tube).

The fact that International Commission on Radiological Protection (ICRP) decreased the annual dose limit for the eye lens from 150 mSv to 20 mSv [1] caused an increased interest in eye lens dosimetry challenging the scientific community for the development of new calibration procedures, eye lens dosemeters and eye lens monitoring procedures in order to implement them in real-life workplace situations [2, 3].

Predrag Božović is with the School of Electrical Engineering, University of Belgrade, 73 Bulevar kralja Aleksandra, 11020 Belgrade, Serbia and Vinca Nuclear Science Institute, University of Belgrade, 12-14 M.P.Alasa, Vinca, Belgrade (bozovic@vinca.rs)

Olivera Ciraj-Bjelac is with the School of Electrical Engineering, University of Belgrade, 73 Bulevar kralja Aleksandra, 11020 Belgrade, Serbia and Vinca Nuclear Science Institute, University of Belgrade, 12-14 M.P.Alasa, Vinca, Belgrade (ociraj@vinca.rs)

Danijela Aranđić is with the School of Electrical Engineering, University of Belgrade, 73 Bulevar kralja Aleksandra, 11020 Belgrade, Serbia and Vinca Nuclear Science Institute, University of Belgrade, 12-14 M.P.Alasa, Vinca, Belgrade (darandjic@vinca.rs)

Sandra Ćeklić is with Vinca Nuclear Science Institute, University of Belgrade, 12-14 M.P.Alasa, Vinca, Belgrade (csandra@vinca.rs)

In interventional procedures the medical staff already wears a whole body dosimeter and in many cases a second one is needed for the so called double dosimetry. In some cases extremity dosimeters are also used for the same staff. Moreover, for protection purposes, the staff in interventional procedures is asked to wear lead apron and thyroid collar and to use ceiling suspended shield and/or lead glasses. Additionally, the position of the nurses during procedures, which is not as far from the x-ray tube as technicians, and not as covered with ceiling suspended shield (lead glass) as doctors can considerably exposes nurses to ionizing radiation.

With these facts in mind and their constant movement and assistance to the doctor during the procedures, adding another dosimeter for eye lenses can prove to be overwhelming for nurses. Therefore, there is a need for establishing a simple eye lens monitoring procedure without increasing the number of dosimeters worn by the medical staff.

Monte Carlo method provides a way to get an estimate of doses to the eye lens simulating the work environment of staff involved in interventional procedures [4]. One such computer code is MCNP, a general-purpose Monte Carlo code package that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. The MCNP program code is maintained by Los Alamos National Laboratory [5].

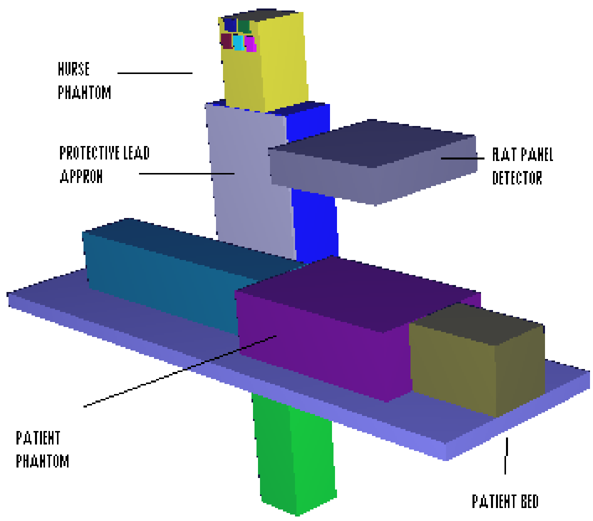


Fig. 1. MCNPX simulation setup

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TABLE I
LEFT AND RIGHT EYE LENS DOSE WHEN NO PROTECTIVE EQUIPMENT IS USED (10^-4 μSv)

| Projection | Eye lens | Tube voltage (kV) | | | |
|---|---|---|---|---|---|
| | | 80 | 90 | 100 | 110 |
| PA | Left | 12.36 | 14.61 | 12.81 | 11.88 |
| | Right | 10.53 | 12.27 | 11.25 | 10.05 |
| RAO | Left | 10.98 | 12.21 | 11.43 | 10.83 |
| | Right | 8.04 | 9.12 | 8.73 | 8.04 |
| LAO | Left | 4.98 | 5.13 | 4.89 | 4.89 |
| | Right | 4.35 | 4.53 | 4.41 | 4.44 |

## II. MATERIALS AND METHOD

Left and right eye lens doses were estimated by simulating five TL dosimeters. One is placed between eyes, two on the outside and two above the eyes. This way dose to each eye lens is estimated as an average of three tallies that surround the eye. The tally of choice was F6 tally, which provides user with the energy deposition averaged over a cell in terms of MeV/g, closely related to the absorbed dose (Figure 1).

Combinations where both lead apron and glasses are applied, only lead apron, only lead glasses and none of the protective equipment (PE) are utilized were simulated.

Simulations also included three projections of the x-ray tube. Projections were posterior anterior (PA) in which the tube is directly beneath the patient and two anterior oblique projections, left (LAO) and right (RAO), in which the x-ray tube is positioned to +45 and -45 degrees, respectively as shown in Figure 2.

X-ray spectrum was calculated using spectrum processor described in IPEM Report 78 [6] for tube voltages ranging from 80 kV to 110 kV.

Simulations were performed using MCNPX program code. Number of simulated particles for each simulation was 3 x $10^8$.

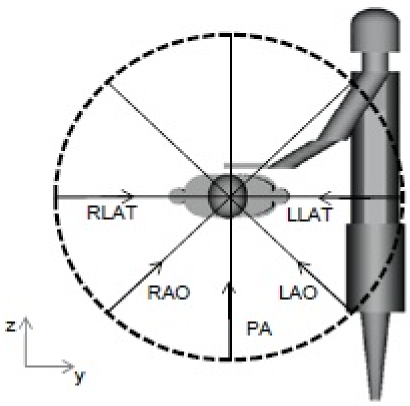


Fig. 2. X-ray tube angulations with transversal view of the patient phantom and side view of the nurse phantom

## III. RESULTS

Table I shows the doses to the left and right lens for all projections and tube voltages when no protective equipment is applied. Doses are given in terms of μSv.

In Table II protective equipment reduction factors are presented.

TABLE II
PROTECTIVE EQUIPMENT (PE) REDUCTION FACTORS

| Projection | PA | | RAO | | LAO | |
|---|---|---|---|---|---|---|
| PE | L | R | L | R | L | R |
| Glass | 2.8 | 3.9 | 1.9 | 2.3 | 5.2 | 4.8 |
| Ceil | 1.0 | 1.0 | 1.1 | 1.1 | 1.3 | 1.2 |
| Both | 2.9 | 3.9 | 2.4 | 2.6 | 5.3 | 4.9 |

Figure 3 gives left and right eye lens doses when all protective equipment is utilized. Doses are given in terms of μSv.

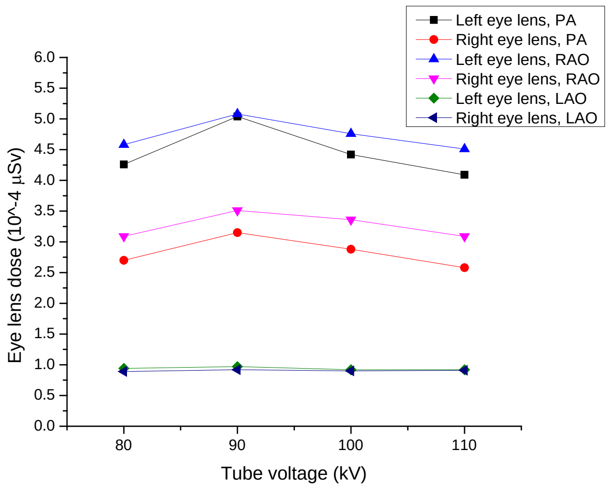


Fig. 3. Left and right eye lens dose when both protective equipment are applied

## IV. DISCUSSION

The main concern for radiation protection of staff in interventional procedures is scatter radiation from patients. For x-rays, the dominant direction of scatter radiation is towards the tube.

Doses from RAO position are greater than LAO in case when there is no suspended ceiling shield since both primary and scatter radiation can reach the nurse position. This however changes when protective equipment is used because suspended ceiling shield can mask nurse position better from scatter radiation, which can be seen from higher reduction factors for LAO than RAO.

We can see that highest doses are in PA projection because the largest portion of scatter radiation reaches the nurse position.

From Table II we can observe that lead glasses provide good reduction factor, while one suspended ceiling shield can mask nurse position depending on the x-ray tube projection. Adding additional suspend ceiling shield in the bottom half of patient table (where most of the nurses are positioned) can further improve reduction factors.

There are differences between left and right eye lens dose due to the orientation of nurse phantom head which is directly to the patient (as an representative position, considering nurses constant movement during procedure) and angle of the incident photons due to the position of the x-ray tube.

## V. CONCLUSION

In this work we have shown how different protective equipment used with different positions of the tube influences the eye lens dose and how it can be estimated using computer algorithms.

Results presented in this paper are part of ongoing study which includes more detailed simulations for entire staff involved in interventional procedures (doctor, nurse, radiation technician) in order to provide method for easy monitoring of the eye lens dose based on whole body dosimeter. Detailed work involves comparison of estimated dose to the eye lens from TLDs placed on staff head phantoms with estimated dose in modeled eye lens and ratio to the worn whole body dosimeter. Confirmation of this ratio is also carried out by measurements on C-arm x-ray units dedicated for interventional procedures using ionization chambers during routine workplace monitoring.

## ACKNOWLEDGMENT

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## REFERENCES

[1] ICRP, 2012, ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs – Threshold Doses for Tissue Reactions in a Radiation Protection Context, ICRP Publication 118. Ann. ICRP 41(1/2)

[2] O. Ciraj-Bjelac, M. Rehani, K. Sim, H. B. Liew, E. Vano, N. J. Kleinman, “Risk for radiation-induced cataract for staff in interventional cardiology – Is there reason for concern?”, *Catheter Cardiovasc. Interv*. 76 826-34, November 2010

[3] E. Carinou, M. Brodecki, J. Domienik, L. Donadille, C. Koukorava, S. Krim, D. Nikodemova, N. Ruiz-Lopez. M. Sans-Merce, L. Struelens, F. Vanhavere, “Recommendations to reduce extremity and eye lens doses in interventional radiology amd cardiology”, *Radiat. Meas.* 46 (11) 1324-29, November 2011

[4] C. Koukurava, E. Carinou, P. Ferrari, S. Krim, L. Struelens, “Study of the parameters affecting doses operator doses in interventional radiology using Monte Carlo simulations”, *Radiat. Meas.* 46 1216-22, November 2011

[5] D. B. Pelotiwz, MCNPX user’s manual version 2.7.0, LA-CP-11-00438, April 2011.

[6] K. Cranley , B. J. Gilmore, G. W. A. Fogarty and L. Desponds, 1997 IPEM Report 78: Catalogue of Diagnostic X-ray Spectra and Other Data (CD-Rom Edition 1997) (Electronic Version prepared by D Sutton) (York: The Institute of Physics and Engineering in Medicine (IPEM))