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AIR KERMA TO $H_p(3)$ CONVERSION COEFFICIENTS FOR EXPOSURE OF THE HUMAN EYE LENS TO THE SELECTED STANDARD X-RAY BEAM QUALITIES

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Abstract. *International Commission on Radiological Protection (ICRP) has decreased the annual dose limit for the eye lens from 150 mSv down to 20 mSv for occupational exposures. The operational quantity Hp (3) has been defined for eye lens dosimetry, while cylindrical phantom approximating the shape of a head was suggested for calibration purposes. The aim of the work was to provide a set of conversion coefficients that could contribute to improving the overall quality of eye lens dose assessment. The work investigated the air kerma to Hp(3,ι)conversion coefficients, Hp(3,ι)/Ka (in Sv/Gy), based on Monte Carlo simulations for a standard beam qualities, different angulations and suitable cylindrical phantom. For incident angles ι from 0º to 90º, the conversion coefficients Hp(3,ι)/Ka were in the range 0.44-0.88 for N-40, 0.72-1.06 for N-60, 0.91-1.63 for N-80, 1.08-1.52 for N-100, 1.22- 1.62 for N-120 and 0.14-1.56 for N-150 beam quality. The conversion factors Hp(3)/Ka provided in this work are related to standard beam qualities readily available in the calibration laboratories and are suitable for application in numerous workplace situations in medicine and industry.*

Key words: *eye lens, medium energy X-Rays, MCNP5/X, conversion coefficients*

1. INTRODUCTION

Numerous studies have demonstrated that the lens of the eye is more sensitive to ionizing radiation than previously thought, indicated that radiation risk has been significantly underestimated and that threshold for cataract development in the eye lens, might be much lower than it was previously thought [1-6]. Interventional radiology and cardiology are among areas with high potential for risk to eye lens. If radiation protection is not practiced, the eye dose to workers involved in interventional radiology or cardiology procedures can reach or exceed the regulatory limit. There are recent reports of eye lens injuries among interventionalists and support professionals in interventional suite [3-5]. The International Atomic Energy Agency (IAEA) initiated a study in 2008 called RELID (Retrospective Evaluation of Lens Injuries and Dose) to examine the eyes of medical and paramedical personnel involved in interventional suits [4]. The reported results from these studies showed increased prevalence of radiation induced lens injuries [1,2,6].

Consequently, the International Commission on Radiological protection (ICRP) proposed a reduction of dose limit for eye lens from 150 mSv to 20 mSv per year [7]. This 7.5 fold reduction of a dose limit has attracted great attention and eye lens dosimetry has become a very intensive research area, including development of new dosimeters, calibration procedures and eye lens monitoring arrangements in various fields of application of ionizing radiation [8-15].

Operational quantities for area and individual monitoring of external exposures have been defined by International Commission on Radiological Units and measurements (ICRU). The *H*p(3) is recommended as operational quantity for eye lens monitoring. It is the dose equivalent in ICRU (soft) tissue at an appropriate depth of 3 mm, below a specified point on the human body [16-17].

The lens of the eye dose, as organ dose is not directly measurable. It is usually assessed by measuring the above mentioned operational quantity *H*p(3), at a position on the head near to the eye. Until recently this quantity has not commonly been in use and respective dosimeters were rarely available. However, in the light of the most recent scientific findings, accurate dosimetry is important for investigation of correlation of radiation effects and radiation dose, for verification of compliance with regulatory dose limits and it certainly contributes to better radiation protection.

A number of papers addressed the question of occupational lens exposure from both a dosimetric and epidemiological point of view . Those studies were carried out to investigate various aspects of the eye dosimetry, as development of new dedicated eye dosimeters and calibration procedures, clinical studies aimed to design the methodology and assess eye lens dose levels, monitoring arrangements using

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different types of dosimeters, correlations of eye lens dose with patient dose indices and methods for retrospective dose assessment [9, 11-15].

The need for eye lens dose monitoring increased interest for the calculation of conversion coefficients from air kerma (Ka) to *H*p(3) for photons [13]. Recently, activities carried out under the ORAMED (Optimisation of RAdiation protection for MEDical staff) calculation of the conversion factors from air kerma to *H*p(3) for photons, electrons and neutrons [8,9,14]. In addition, a new phantom, shaped as a right cylinder (20 cm in diameter) and made of the ICRU 4-element tissue, has been proposed for calculating the conversion coefficient from air kerma to *H*p(3) [13,15]. This cylindrical shape is closer to the elliptical shape of the head and more realistic in terms of the position of the eye lens within the head. This improves accuracy compared to calculations performed in the slab phantom [13, 14].

The aim of the work was to provide a set of conversion coefficients from air kerma to *H*p(3) for reference radiation beam qualities defined in the International Organization for Standardization (ISO) publication ISO 4037, that are commonly used in calibration laboratories, that could contribute that to improve the overall quality of eye lens dose assessment procedures in workplace situation involving *exposure to medium energy X-rays*.

2. MATERIALS AND METHOD

The work investigated the lens of the eye dose to air kerma conversion coefficients, *Hp(3,ı)/Ka* (in Sv/Gy), based on Monte Carlo simulations using a standard beam qualities and suitable cylindrical phantom. Calculations have been performed by means of the MCNP5/X code using Monte Carlo method [18], which was used to simulate photon transport from the source to the volume of interest. For this purpose, calculation of conversion coefficients was performed by using a phantom, with the shape of cylinder, as presented in Figure 1.

Dimensions of cylinder is 20 cm in diameter and 20 cm in height, with the wall thickness 0.5 cm, with basic material structure in the wallof poly-methyl-methacrylate (PMMA), and inside area was filled with water.

The source was modeled as a square parallel beam of 20 x 20 cm². An aligned and expanded field of photons irradiated the entire phantom in anterior-posterior AP geometry at a distance of 1 m from the phantoms. The calculation of photons transport was modeled and performed for the angulation ranging from 0° to 90°.

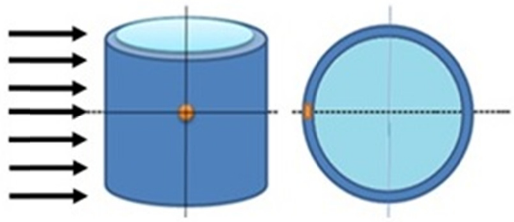

Fig 1. The cylindrical modeled of head phantoms

The tally used to score the kerma was 'F6' with 1-keV energy cut-off for photons. Tally F6 gives the energy deposited in cell (in MeV per gram). Totally 10^8 simulations were run in order to achieve a small calculation uncertainty, not more of 3 percent. Beam qualities used for calculation of the conversion factors *Hp(3,ı)/Ka* were narrow standard series on photon reference radiation defined in the International Organization for Standardization (ISO) publication ISO 4037 [19] , as presented in Table 1. Spectra was caluculated based on methods described elesewhere [20]
The calculation of conversion coefficients *Hp(3,ı)/Ka*, requires independent calculation of Ka and *H*p(3). The MCNP F6 tally was used for calculating air kerma without phantom in sphere with air of radius 10 cm. The personal dose equivalent *H*p(3) is defined as the dose equivalent in tissue at 3 mm depth in the phantom. As it is recommended to take the quality factor Q equal to 1 for photons *H*p(3) is equal to the absorbed dose in these specified conditions.
The centers of the scoring volumes were positioned on the midplane at a depth of 3 mm. The thickness along the radius is 0.5 mm, the height is 2 cm around the axial midplane.

3. RESULTS AND DISCUSSION

The conversion factors *H*p(3)/Ka for different angulations and different beam qualities are presented in the Table 1 and Figure 2.

Table 1 conversion factors *H*p(3)/Ka for different angulations and different beam qualities

Angle (degree)	Hp(3)/Ka [Sv/Gy]					
	N 40	*N* 60	*N* 80	*N* 100	*N* 120	*N* 150
0°	0.88	1.06	1.63	1.52	1.62	1.56
30°	0.88	1.14	1.39	1.56	1.35	1.38
60°	0.75	0.93	1.29	1.42	1.43	1.44
90°	0.44	0.73	0.91	1.08	1.22	1.14

The cylindrical phantom was selected to approximate to the best possible extend the shape of the head related to angle dependence and depth (3 mm) at which the operational quantity is defined due to the simultaneous attenuation of the medium and its scattering properties [15].

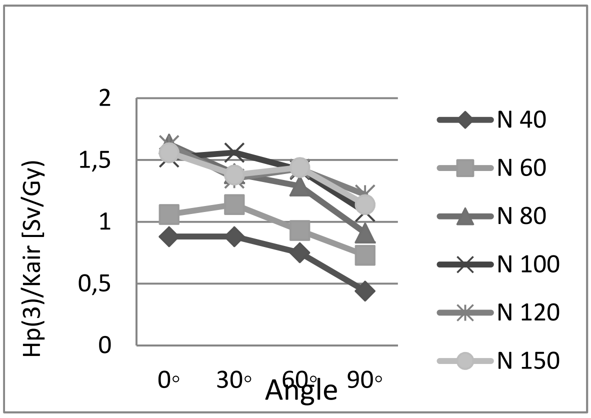

Fig 2. Conversion coefficients Hp(3)/Ka calculated for different beam qualities for different incident angles

The phantom of the same external shape but different materials (cylindrical, with a 0.5-cm-thick PMMA wall, filled with water) has been proposed for the calibration of eye dosimeters in laboratory conditions.

As in realistic conditions during calibrations in the laboratory the dosemeter is placed on the surface of the phantom, and the aim of such dosimeters is to measure dose to the lens of the eye, the calculations of conversion factors were performed in the similar geometrical conditions, i.e. scoring volumes positions were selected to be as close as possible to position of dosemeter and the eye lens.

However, standard x-ray beam qualities are used for calibration of dosemeters in the field of radiation protection, as N and W series [15, 19], so provision of conversion factors for these beam is of huge practical importance. For calibration of dosemeters used in interventional radiology and cardiology procedures, it is very important to select proper beam quality for calibration, as close as possible to the beam qualities used in real clinical conditions. In addition, the dosemeters must have an adequate energy and angular response. Another issue related to practical use of eye lens dosimeters is x-ray tube orientation, as x-ray tube can be moved during the intervention, which has an influence to the angle of incidence of the x-ray beam. Having in mind typical x—ray tube angulations, i.e. projections used during interventional procedures, conversion factors for different angulations are also provided in this work.

4. CONCLUSION

In this study, a set of energy- and angular-dependent conversion coefficients (Hp(3)/Ka) in the newly proposed cylindrical phantom for calibration of eye lens dosimeters have been calculated with the Monte-Carlo code MCNP5/X. The *H*p(3)/Ka conversion coefficients have been determined for standard photon beam qualities denoted as ISO N series in the range of tube voltages from 40 to 150 kV. The conversion factors *H*p(3)/Ka provided in this work are related to standard beam qualities (N40 to N150) readily available in the calibration laboratories and they are suitable for application in numerous workplace situations in medicine and industry.

The provided conversion coefficients could be applied in calibration procedures utilized in calibration laboratories and thus, could contribute to the implementation and accuracy of the dosimetry measurements for the eye lens exposure.

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REFERENCES

1. Ainsbury, E., Bouffler,S., Dörr, W., Graw, J., Muirhead,J., Edwards, A., Coope,r C. RadiationCataractogenesis: A Review of Recent Studies. Radiat. Res. 172, 1-9(2009).
2. Shore, R.E., Neriishi, K., Nakashima, E. Epidemiological Studies of Cataract Risk at Low to Moderate radiation Doses: (Not) Seeing is Believing. Radiat. Res. 174, 889-894 (2010).
3. Ciraj-Bjelac, O, et al. Radiation-induced eye lens changes and risk for cataract in interventional cardiology. Cardiology. 2012;123(3):168-71.
4. Vano, E, et al Radiation cataract risk in interventional cardiology personnel. Radiat Res. 2010 Oct;174(4):490-5.
5. Ciraj-Bjelac, O., et al.Risk for radiation induced cataract for staff in interventional cardiology: Is there reason for concern? Catheter. Cardiovasc.Interv. 76, 826-834(2010).
6. Jacob, S, et al.Interventional cardiologists and risk of radiation-induced cataract Results of a French multicenter observational study. Int J Cardiol (2012), doi:10.1016/j.ijcard.2012.04.124
7. International Commission on Radiological Protection. 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), 2012
8. Gualdrini, G, et al" "Air kerma to *H*P(3) conversion coefficients for photons from 10 keV to 10 MeV, calculated in a cylindrical phantom." Radiat Prot Dosemetry. 2013 May;154(4):517-21.
9. Behrens, R. Air kerma to *H*p(3) conversion coefficients for a new cylinder phantom for photon reference radiation qualities. "Radiat. Prot. Dosim. 151(3), 450-455, 2012.
10. Donadille, L, et al. Staff eye lens and extremity exposure in interventional cardiology: Results of the ORAMED project. Radiation Measurements 46 (2011) 1203e1209
11. L. Struelens, E. Carinou, I. Clairand, L. Donadille, M. Ginjaume, C. Koukorava, S. Krim, H. Mol, M. Sans-Merce, F. Vanhavere Use of active personal dosemeters in interventional radiology and cardiology: Tests in hospitals – ORAMED project. Radiation Measurements, Volume 46, Issue 11, November 2011, Pages 1258-1261
12. I. Clairand, J.-M. Bordy, E. Carinou, et al. Use of active personal dosemeters in interventional radiology and cardiology: Tests in laboratory conditions and recommendations - ORAMED

project. Radiation Measurements, Volume 46, Issue 11, November 2011, Pages 1252-1257
13. J.M. Bordy J. Daures, M. Denozière et al. Proposals for the type tests criteria and calibration conditions of passive eye lens dosemeters to be used in interventional cardiology and radiology workplaces. Radiation Measurements, Volume 46, Issue 11, November 2011, Pages 1235-1238
14. Daures J, Gouriou J, Bordy JM. Monte Carlo determination of the conversion coefficients Hp(3)/Ka in a right cylinder phantom with 'PENELOPE' code. Comparison with 'MCNP' simulations. Radiat Prot Dosimetry. 2011 Mar;144(1-4):37-42.
15. Bordy JM, Gualdrini G, Daures J, Mariotti F. Principles for the design and calibration of radiation protection dosemeters for operational and protection quantities for eye lens dosimetry. Radiat Prot Dosimetry. 2011 Mar;144(1-4):257-61.
16. International Commission on Radiological Protection. Conversion coefficients for use in radiological protection against external radiation. ICRP Publication 74. Pergamon Press (1998).
17. International Commission on Radiation Units and Measurements. Conversion coefficients for use in radiological protection against external radiation. ICRU Report 57. ICRU (1998).
18. X-5 Monte Carlo Team (2003) MCNP–a General Monte Carlo N-Particle Transport Code, Version 5 Vol. I: Overview and Theory. Los Alamos, NM: Los Alamos National Laboratory; LA- UR- 03-1987
19. International Organization for Standardization, 1996. ISO 4037-3, X and gamma referenceradiations for calibrating dosemeters and dose rate meters and for determining their response as a function of photon energy, Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence. ISO, Geneva.
20. Poludniowski G, Landry G, DeBlois F, Evans PM, Verhaegen F. SpekCalc: a program to calculate photon spectra from tungsten anode x-ray tubes. Phys Med Biol. 2009 Oct 7;54(19):N433-8.