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## FIRST EURADOS INTERCOMPARISON EXERCISE OF EYE LENS DOSEMETERS FOR MEDICAL APPLICATIONS

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In the context of the decrease of the eye lens dose limit for occupational exposure to 20 mSv per year stated by the recent revision of the European Basic Safety Standards Directive 2013/59/EURATOM, the European Radiation Dosimetry Group (EURADOS) has organized in 2014, for the first time, an intercomparison exercise for eye lens dosimeters. The main objective was to assess the capabilities of the passive eye lens dosimeters currently in use in Europe for occupational monitoring in medical fields. A total of 20 European individual monitoring services from 15 different countries have participated. The dosimeters provided by the participants were all composed of thermoluminescent detectors, of various types and designs. The irradiations were carried out with several photon fields chosen to cover the energy and angle ranges encountered in medical workplaces. Participants were asked to report the doses in terms of  $H_p(3)$  using their routine protocol. The results provided by each participant were compared to the reference delivered doses. All the results were anonymously analyzed. Results are globally satisfactory since, among the 20 participants, 17 were able to provide 90% of their response in accordance to the ISO 14146 standard requirements.

For many years, the European Radiation Dosimetry Group (EURADOS) has been organizing intercomparison (IC) exercises<sup>(1)</sup> dedicated to Individual Monitoring Services (IMS). These exercises give IMS the opportunity to compare results with other participants and develop plans for improving their dosimetry systems. Up to now, EURADOS organized several IC for whole-body and extremity dosimeters and one for environmental dosimeters<sup>(2)</sup>.

In the context of the decrease of the eye lens dose limit for occupational exposure to 20 mSv per year stated by the recent revision of the European Basic Safety Standards Directive 2013/59/EURATOM<sup>(3)</sup>, EURADOS organized in 2014, for the first time, an IC exercise specifically dedicated for eye lens dosimeters in the medical field, so called IC2014<sub>eye</sub>.

### MATERIAL AND METHODS

#### Scope and organization of IC2014<sub>eye</sub>

IC2014<sub>eye</sub> was organized to assess the capabilities of the passive eye lens dosimeters currently in use in Europe for occupational monitoring in the medical field to measure the personal dose equivalent  $H_p(3)$ .

The eye lens dosimeters were irradiated with Cs-137 sources as a reference, and with other photon fields chosen to cover the energy and angle ranges encountered at medical workplaces.

An Organization Group (OG) composed of members of EURADOS Working Group 12 “Dosimetry in medical imaging” was appointed to organize and realize this IC. All participants were requested to prepare their dosimeters according to their normal procedures and to label them with codes provided by the OG coordinator in charge of the reception and dispatching of the dosimeters to the irradiation laboratories. Participants were asked to report the doses in terms of  $H_p(3)$  using their routine protocol. All the data processed by the OG members were treated confidentially using an identification code composed of three letters (XXX) assigned to each participant. This IC was designed to be a blind test for all participants who had to report their results without knowing the details of the irradiation plan nor the reference dose values. The only information they had was that the irradiations were performed with several photon fields similar to the ones encountered at medical workplaces.

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## Participants

A total of 20 European IMS from 15 different countries participated (Austria, Belgium, Czech Republic, France, Greece, Italy, Lithuania, Poland, Rumania, Serbia, Slovakia, Spain, Switzerland, United Kingdom and Ukraine).

Participation was on a voluntary basis but required payment of a participation fee.

The dosimeters provided by the participants were all composed of thermoluminescent detectors. Among the 20 participants, 9 provided the Eye-D™ system developed during the ORAMED European project<sup>(4)</sup> and the other participants provided different systems of various designs as presented in Figure 1.

In addition, each participant was kindly requested to fill in a questionnaire indicating, in particular, the type of detector included in the eye lens dosimeter and the calibration method.



Figure 1. Photo of the different types of dosimeters provided by the participants for the IC2014<sub>eye</sub>.

## Methodology followed for irradiations

Ten irradiation configurations were chosen for this IC. Table 1 summarizes the dose range, angle and radiation beam quality for each setup. S-Cs and narrow radiation field series defined in ISO 4037–part 1 standard<sup>(5)</sup> and RQR diagnostic fields defined in IEC 61267 standard<sup>(6)</sup> were used together with a so-called “realistic field” representative of the scattered field encountered in interventional radiology at the level of the operator<sup>(7)</sup>.

Irradiations were performed on a cylindrical head phantom (20 cm \* 20 cm)<sup>(8)</sup> developed during the ORAMED European project<sup>(4)</sup>. Conversion coefficients to relate air kerma to  $H_p(3)$  were taken from Behrens<sup>(9)</sup> for ISO 4037 qualities and from Principi et. al<sup>(10)</sup> for IEC 61267 qualities. For the “realistic field” the conversion coefficient was calculated with PENELOPE Monte Carlo code<sup>(11)</sup> as described in EURADOS 2012-02 report<sup>(4)</sup>.

Two dosimeters of each participant were irradiated for each setup. The irradiations were carried out at SCK-

CEN (Belgium), UPC (Spain), CEA-LNHB (France) and IRSN (France) calibration laboratories.

## Background and transit dose control

In total, each participant provided 38 dosimeters. Twenty dosimeters were used for the irradiations. Twelve dosimeters were reserved for transit dose correction (3 dosimeters were dispatched to each of the 4 irradiation laboratories); the transit dose value was taken into account by the OG.

The background was subtracted by each participant according to the IMS routine procedure.

Six dosimeters were reserved to be used by the irradiation laboratories in case of damage or false irradiation. In the end, only a very few dosimeters were used for this purpose.

**Table 1. Irradiation plan of the “IC2014eye” intercomparison: radiation qualities and angles of incidence, mean energy (keV) and range of imparted doses in terms of personal dose equivalent  $H_p(3)$  in mSv.**

Radiation quality and angle of incidence	Mean energy (keV)	Dose range ( $H_p(3)$ , mSv)
S-Cs; 0°	667	0.4 – 0.5
S-Cs; 0°	667	2.0 – 2.2
S-Cs; 60°	667	2.0 – 2.1
N-40; 0°	33	3.0 – 3.1
N-60; 0°	48	3.0 – 3.1
N-80; 0°	65	3.0 – 3.1
RQR6; 0°	44	2.6 – 2.7
RQR6; 45°	44	2.5 – 2.6
RQR6; 75°	44	2.1 - 2.2
Realistic field <sup>1</sup>	45	0.9 - 1.0

<sup>1</sup>Specific configuration representative of the scattered field encountered in interventional radiology at the level of the operator<sup>(7)</sup>.

## Criteria for the evaluation of the results

The numerical results in this intercomparison are reported as the dosimeter response R, where R is defined as the value of the dose measured by the participant and corrected for background and transit dose,  $H_p(3)$ , divided by the reference value,  $H_p(3)_c$ , given by the irradiation laboratory.

For the analysis of the global results, the performance limits according to the ISO 14146 standard<sup>(12)</sup>, commonly known as «trumpet curves» were adopted:

$$\frac{1}{F} \left( 1 - \frac{2H_0}{H_0 + H_c} \right) \leq R \leq F \left( 1 + \frac{H_0}{2H_0 + H_c} \right) \quad (1)$$

where  $H_c$  is the conventional true value,  $R$  is the response,  $F = 1.5$  following the recommendations of ICRP 75 report<sup>(13)</sup> and  $H_0$  is the “lower limit of the dose range for which the system has been approved” as it is mentioned in the ISO 14146 standard<sup>(12)</sup>. For this IC, each participant was not asked for individual values of  $H_0$ . Instead, a value of 0.085 mSv was chosen for all participants, assuming a “lower limit of the dose range” of 1 mSv in a year, and an issuing frequency of 12 per year. This value has already been chosen in the case of a previous EURADOS IC for whole body dosimeters<sup>(14)</sup>.

RESULTS AND DISCUSSION

Description and analysis of the results

Figure 2 gives a general overview of the response values  $R$  as a function of the reference doses  $H_c$  and shows that 93% of the results are within the trumpet curves built according to equation (1). This percentage differs based on the various irradiation setups. It is 100% for S-Cs and N-80 setups, since these qualities were chosen for the calibration by most of the participants. This value decreases slightly for lower energy configurations: it is equal to 95% for the realistic field and to 86% for N-40, N-60 and RQR6 setups. The lowest value is 77% for the “RQR6; 75°” setup which corresponds to low energy and large angle irradiation setup.

Figure 3 gives the distribution of the response values for each irradiation setup using a box plot representation showing the minimum, 1<sup>st</sup> quartile, median, 3<sup>rd</sup> quartile and maximum responses. It can be noticed that the median of responses is very close to 1 for S-Cs beam quality setups, whereas the median of the responses ranges from 0.95 to 1.16 for N series and from 1.13 to 1.23 for RQR series. The median of responses is equal to 1.1 for the realistic field. Among the 20 participants, for 14 of them the response is 100% within the limits set by the ISO 14146 standard<sup>(12)</sup> for all setups, while for 17 participants more than 90% of the measurements are within the limits. Regarding the outliers, 1 participant is out of the limits for low energy setups, 3 are out of the limits for large angle setups and 2 are out of the limits for both low energy and large angle setups.

Figure 4 presents the distribution of results, using box plots, for each participant in an anonymous manner. A relatively large variability is observed among participants, the median of responses ranges from 0.72 to 1.67. Using the questionnaires filled by the participants, the information regarding the calibration method is of interest to help in the interpretation of the results. In particular, regarding the calibration beam

quality, 9 participants use pure S-Cs, 3 use mixed S-Cs and X-ray and 8 use various X-ray spectra. It appears that all the outliers for setups characterized by low energies use pure S-Cs to perform their calibration. Still, a majority of participants using pure S-Cs has correct results. The outliers for large angle setups can mainly be explained by the shape of the dosimeters. This type of analysis cannot be conducted deeper in such a study to respect the anonymity of results.

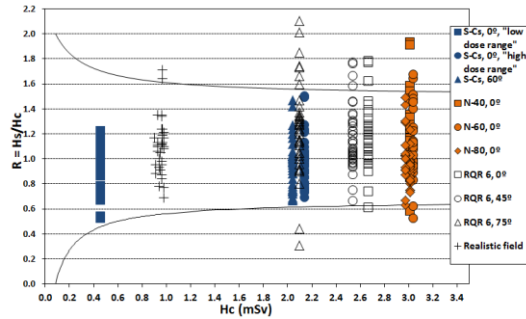


Figure 2. Summary of all reported response values  $R$  as a function of reference doses  $H_c$ . The trumpet curves are built according to equation (1).

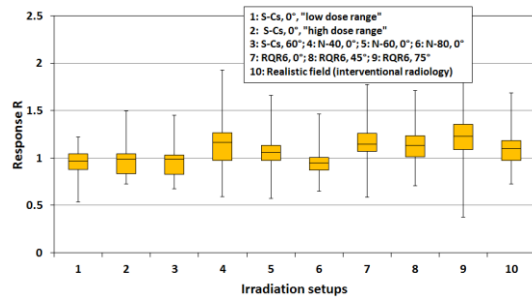


Figure 3. Box plot showing the minimum, 1<sup>st</sup> quartile, median, 3<sup>rd</sup> quartile and maximum responses,  $R$ , per irradiation setup.

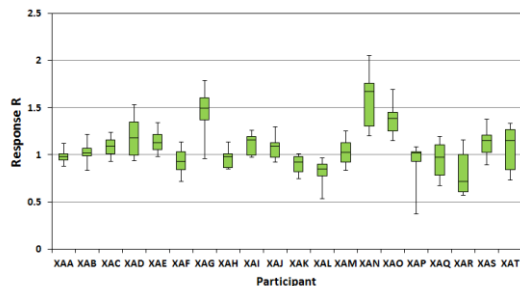


Figure 4. Box plot showing the minimum, 1<sup>st</sup> quartile, median, 3<sup>rd</sup> quartile and maximum responses,  $R$ , for each participant.

## CONCLUSION

EURADOS organized, for the first time, an IC exercise specifically dedicated for eye lens dosimeters in the medical field. This IC gives an overview of the different dosimetric systems currently available in Europe for eye lens dose monitoring. This is particularly of interest in the context of the decrease of the eye lens dose limit for occupational exposure to 20 mSv per year.

Results are globally satisfactory since, among the 20 participants, 17 of them are able to provide 90% of their responses in accordance with the ISO 14146 standard<sup>(12)</sup> requirements. For a minority of participants some discrepancies compared to reference doses were observed for the irradiation setups characterized by large angles and/or low energies. Some participants could improve the performance of their system by improving their calibration methodology.

This type of IC on eye lens dosimeters should be performed regularly through the self-sustained programme of regular IC of EURADOS.

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