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Abstract
A questionnaire was developed by the members of WG12 of EURADOS in order to establish an overview of the current status of eye lens radiation dose monitoring in hospitals. The questionnaire was sent to medical physicists and radiation protection officers in hospitals across Europe. Specific topics were addressed in the questionnaire such as: knowledge of the proposed eye lens dose limit; monitoring and dosimetry issues; training and radiation protection measures. The results of the survey highlighted that the new eye lens dose limit can be exceeded in interventional radiology procedures and that eye lens protection is crucial. Personnel should be properly trained in how to use protective equipment in order to keep eye lens doses as low as reasonably achievable. Finally, the results also highlighted the need to improve the design of eye dosemeters in order to ensure satisfactory use by workers.

Keywords: questionnaire, eye lens limit, eye lens dosemeters, radiation protection

(Some figures may appear in colour only in the online journal)

1. Introduction

In the context of the reduced eye lens dose limit proposed by the ICRP [1] and the subsequent adoption of this limit by the council of the European Union [2], the members of EURADOS Working Group 12 (WG12) attempted to assess the current status of eye lens dose monitoring in European countries.
EURADOS (www.eurados.org/) is a network of more than 50 European institutions and 250 scientists working in the field of dosimetry and radiation monitoring. More specifically, one of the primary aims of WG12 of EURADOS (Dosimetry in medical imaging) is to increase the understanding of eye lens dose issues for medical staff. This focus on medical workers is in line with a recent task group report from IRPA [3], which concluded that ‘there is a very broad consensus that the principal impact of the new dose limit will be in the medical sector primarily in interventional radiology and cardiology’.

In order to establish an overview of the current status of eye lens dosimetry issues in hospitals, a questionnaire was developed by the members of WG12 and sent to medical physicists and radiation protection officers (RPO) in hospitals across Europe. The questionnaire was intended for hospitals with interventional radiology (IR) and nuclear medicine departments (NM). Specific topics addressed in the questionnaire included: knowledge of the proposed eye lens dose limit; monitoring and dosimetry issues; training and radiation protection measures. Conclusions drawn from the results of the survey are presented in this work.

2. Design of questionnaire

The questionnaire was designed so that it could be answered without being overly time consuming. It was divided into three main sections. The first section covers introductory questions about the knowledge of the new eye lens limit for occupationally exposed staff and asks if any specific eye dose studies have been performed. The second section was designed to establish: the number of personnel that are currently monitored with whole body and eye lens dosemeters; the length of the monitoring period; the maximum doses recorded and the methodology used to assess the eye lens doses. Questions were set out separately for the NM and IR departments. In this second part there are also questions about the eye lens dosemeters, including which dosemeter is used and questions about where it is worn. In the last section questions were asked about training of workers, specifically related to eye lens issues, as well as questions about the respective radiation protection measures used in the hospital. Space for entering comments as free-text was provided at the end.

The questionnaire was disseminated electronically via email. The email included a hyperlink to the web address for accessing the questionnaire. An introductory letter was also provided at the web address to explain the main objective of the questionnaire. Participants were reminded that the data would be used anonymously; however, an email address was requested in case any clarification was required. In order to obtain a representative sample of responses from European countries, the first contact with hospitals was made through the members of WG12 who sent the questionnaire link to hospitals. After receiving the first results (November 2013–February 2014) we identified that some countries who are very active in the field of radiation protection, and more specifically in the area of eye lens monitoring, had not been contacted or not responded. Contact persons were established in these countries and a second round of emails was sent out during March 2014.

3. Limitations

The following results should be interpreted taking into account the distribution of the questionnaire, which could not guarantee a representative sample of all countries. Moreover, some hospitals that did answer the questionnaire did not provide clear answers or left many answers blank, especially in relation to the NM sections. The reason for these blanks was not always clear, whether it was due to the fact that the questions were not applicable or because no
information was available or, indeed, because the information requested was not clear. We contacted these responders again and asked them for clarification about the specific data. In some cases, the information, related to the type of the specific department, was gathered from the official websites of the hospitals and respective changes were introduced. The updated answers were then included in the analysis. Nonetheless, some useful data about the current situation around eye lens monitoring in Europe has been collated, analysed and summarised below.

4. Number of responses

201 responses in total were received. 195 responses were analysed and the remaining 6 were excluded as they came from countries outside of Europe. The responses were a sample of reasonable size, from 23 European countries. The response representation per country is shown in figure 1.

Taking into account the population of each country there is a good representation of most of the countries with the exception of Ukraine.

5. Knowledge about the change in the eye lens dose limit

93% of the responses stated that they are familiar with the change in the eye lens limit for occupationally exposed personnel. From these, about half of them (55%) have already performed some specific eye dose monitoring studies. The number of hospitals in each country that have performed (Yes column) or not performed (No column) any specific study is shown in table 1.

6. Eye lens monitoring and dosimetry issues

165 hospitals responded in relation to both IR and NM departments, 29 referred only to IR and 1 only to NM. Most of the results were analysed separately for the two types of workplaces.
6.1. Frequency of monitoring

The frequency of eye lens monitoring (either by direct measurements or estimation) is shown in figure 2. As shown on the graph, in most of the cases (in IR or NM workplaces) the eye lens doses are not measured or estimated. However, there are 38% and 29% of the responses (for IR and NM respectively) where specific studies are performed. Moreover, a lower percentage (25% and 12% for IR and NM respectively) estimates the eye lens doses on monthly basis.

6.2. Annual eye lens doses

The results of the questionnaire on the maximum eye lens dose that is measured or estimated on an annual basis are shown in figure 3. It should be noted that the procedure based on which, the annual doses were calculated, is, in general, not described by the responders. As expected, the estimated or measured eye lens doses are higher in IR workplaces than in NM. For NM the vast majority (81.3%) of the responses lie in the dose range of less than 1 mSv–5 mSv,
whereas for IR 71.5% of the respondents stated that the doses are higher than 5 mSv. For IR, 50% of the answers reported maximum annual eye doses higher than 15 mSv and for 35% of IR responses, the doses are higher than 20 mSv.

6.3. Dosemeters

With regards to the question of how eye lens doses are measured or estimated in both IR and NM, the majority replied that they use a specific eye lens dosimeter for the measurement of the eye lens doses (figure 4). However, in 27% and 18% of cases for IR and NM respectively, they use a whole body dosimeter with a correction factor in order to estimate the eye lens doses. A small percentage uses extremity dosemeters, again with a correction factor, to obtain eye lens doses. In one case active personal dosemeters situated on the collar during IR procedures were used to increase awareness of the eye lens exposure.

If we focus on the responses received from the IR departments who claim that the doses are higher than 20 mSv, then 40% of these cases replied that they use specific eye lens dosemeters.
This probably highlights the fact that in cases where high doses have been identified, dedicated eye lens dosemeters are used. Finally, where a whole body dosemeter is used on the collar in order to estimate the eye lens doses, 48% of respondents perform this monitoring on a routine monthly basis, which shows that, in some countries, there are routine established procedures from which eye lens doses can be collected.

6.4. Positioning of dosemeters

In cases where eye lens dosemeters are used, there was a question about the position of the dosemeter. As shown in figure 5, the position of the dosemeter varies considerably. The least common position for eye lens monitoring is the shoulder. In increasing order, the percentages of the positions for wearing the dosemeters are: between the eyes, behind the lead glasses, on the collar and the most common position is in front of the lead glasses.

When the participants were asked whether the eye dosemeters are comfortable, the answers were almost equally divided between ‘yes’ and ‘no’ (52 and 48% respectively).

7. Knowledge of eye lens doses received and training on radiation protection specifically related to the eye lens

In the majority of cases (91%), the responses show that workers are informed about the individual eye lens doses that they receive. Moreover, 81% of the answers state that workers receive training on radiation protection specifically related to eye lens issues. It should be noted that 45% (IR) and 30% (NM) of the positive answers for training came from countries where specific studies are performed. This depicts the fact that awareness on these issues has been raised, in almost half of the cases for IR, in the framework of dedicated measurement campaigns.
8. Radiation protection equipment

The question for the radiation protection equipment included the use of ceiling suspended screens, lead glasses and lead sheets. The ceiling suspended screen is transparent glass, the most common of which is of 0.5 mm lead equivalent that protects the upper part of the operator’s body. The lead glasses can be of various shapes with or without side protection. The lead sheets are flexible lead drapes that can be placed as close as possible to the patient in order to reduce the scattered dose to the operator’s upper part of the body.

The majority of the responses in IR (96.4%) indicate that workers use protection systems to reduce eye lens doses. In NM, only 31% of the replies are positive, however, several answers included comments to point out that most of the work in NM is performed using structural shielding such as lead glass cabinets and barriers (as opposed to personal protective equipment) which protect the eyes and the rest of the body. In this case, the type of shielding is very much dependent on the radioactive source. Results for use of protective equipment are shown in figure 6.

For the IR workers, the frequency of the use of various protective equipment is shown in figure 7. As indicated in the figure, the ceiling suspended screen is the most used solution for the protection of the operator’s eyes.

In terms of the frequency of use of lead glasses in NM in order to protect the eye lens, almost half of the responses gave a frequency of less than 25%. From those who answered positively about the use of lead glasses in NM the frequency of use of this equipment by the three different specialties (medical doctors, nurses and technologists) is given in figure 8. As it is seen from the figure, for all three specialties, the majority of responses fell into the category of the lowest frequency (<25%).

Finally, regarding the type of lead glasses used, almost 45% of the cases replied that they use lead glasses with the side view partially protected, 40% replied that they use lead glasses with the side view fully protected and only 15% indicated that they use lead glasses without side protection. If we isolate the replies received from the IR workplaces where they indicated doses higher than 20 mSv, the distribution of the eye lead glasses used is shown in figure 9. As can be seen from the figure the highest percentage (53%) of the cases where high doses have been measured or estimated have chosen to use lead glasses with partial side protection and 22% without side protection.
Figure 7. Percentage of the responses about the frequency of the use of the protective equipment in IR (number of answers: 146, 162, 123 and 81 for ceiling suspended screen (a), lead glasses (b), both ceiling and lead glasses (c) and lead sheets (d), respectively).

Figure 8. Percentage of the responses that use lead glasses in NM for the physicians, nurses and technologists (number of responses 30, 30 and 37).
9. Discussion

The main objective for the development of this questionnaire was to determine the current situation in Europe at this transitional period where a new eye lens dose limit has been recommended [1] and adopted in the latest EU Directive [2] but not yet transposed into national legislation.

The response to the questionnaire can be considered reasonably representative having received 195 answers from 23 European countries. The first results of the questionnaire indicate that in most of the countries there is a high level of awareness regarding the decrease in the eye lens dose limit and many studies have been launched in order to investigate the situation from a radiation protection point of view. Within the scope of the current survey, no specific differences have been identified across the various European countries in areas concerning use of dosemeters for the measurement of eye lens doses; radiation protective equipment for the eye lens; and education and training on these issues.

As mentioned in the literature [3–5] personnel working in the medical sector, especially those involved in IR departments, are the ones who are most affected by the new eye lens limit and for this reason the questionnaire was addressed to hospitals. In order to draw conclusions the analysis has been performed separately for IR and NM workplaces whenever possible.

Although there is good awareness of the issues surrounding eye doses, in most of the cases eye lens monitoring is never performed or, it is done within a framework of specific studies. However, there is a significant percent of 25% and 12% (for IR and NM respectively) who responded that they perform routine monthly monitoring of eye lens doses. Almost half of these cases in IR use a whole body dosemeter worn on the collar to estimate eye lens doses. The higher percentage of non performance of eye lens monitoring in NM than in IR is mainly due to preliminary studies [6] where it is indicated that the expected eye lens doses in NM are not of great concern. This is also in line with the results of the question about the maximum

![Figure 9. Distribution of the frequency of the various types of lead glasses for the cases in IR where measured or estimated doses could exceed 20 mSv year⁻¹.](image-url)
eye lens dose in annual basis where it is shown in figure 3 that higher doses are measured or estimated in IR.

The values of maximum eye lens doses in IR provided by the hospitals highlight the need to increase or optimize the use of radiation protection means (35% indicate maximum doses above 20 mSv) and the need for implementing eye lens dose monitoring in this field (50% indicate maximum doses above 15 mSv).

Regarding the method for measuring or estimating eye lens doses, it is indicated that in most of the cases a specific dosemeter or the whole body dosemeter worn on the collar is used to assess the eye lens dose. A significant percentage uses a whole body dosemeter worn on the collar with a correction factor. A small percentage of replies reported that an extremity dosemeter is used with a correction factor. However, only few answers provided details about the applied corrections, and the responses varied considerably.

Where eye lens dosemeters are used, the replies about its position show that dosemeters are distributed in different places. It appears that even though a specific eye lens dosemeter is used, no standard way of wearing exists across Europe at this point in time. Almost half of the replies claimed that the eye lens dosemeters are not comfortable.

In relation to knowledge of eye lens doses and staff training the survey shows that most of the workers are informed about their own dose and they receive training focused on the eye lens radiation protection issues. However, this is not in line with the findings in the literature [7], where it is mentioned that only 36% of the cardiologists were aware of their personal dose values. The discrepancy is probably explained by the fact that the eye lens monitoring is a new procedure and in most of the cases is performed through specific studies. Moreover, the study was performed in Latin America prior to ICRP statement for the new eye lens dose limit [1]. For these reasons staff are nowadays more interested in this ‘hot topic’ and concerned with learning more about the eye lens doses issues than they are for existing whole body routine procedures. In addition, it must be kept in mind that most of the answers to this questionnaire were prepared by radiation protection officers or medical physicists.

As regards the radiation protection means, most of the personnel in IR use some kind of protection for the eye. The most frequent solution for protection is the ceiling suspended screen. This is in agreement with the results of the ISEMIR project conducted by the IAEA [8]. The ceiling suspended screen seems to be preferable since it protects not only the upper part of the operator’s body but also the eyes. The lead glasses seem to be used more frequently than indicated in earlier studies [9] where 36% of the operators wore lead glasses. This is probably due to the fact that more and more studies underline the importance of the radiation protection of the eye lens in IR [10]. One interesting finding is the use of lead glasses in NM where a significant percentage has been noted (43%, 30% and 32% for medical doctors, nurses and technologists respectively). However, this use is not very frequent, because in most cases the structural shielding is sufficient. Further work in the area of NM eye doses would help determine situations where lead glasses are recommended.

Finally, in terms of the shape of the lead glasses, in most cases it is stated that the lead glasses have some kind of side protection. It should be stressed that in some cases where annual doses higher than 20 mSv in IR are expected, lead glasses without full side protection are used.

10. Conclusion

The new eye lens dose limit will have a significant impact in the medical field, especially in the interventional radiology and cardiology sector. Our survey of European hospitals shows
that there is good awareness of the reduced eye dose limit. Many specific eye dose studies have already been performed or are in progress. However, the survey highlights that the new eye lens dose limit can be exceeded for those working with IR, and this is consistent with the existing literature. Guidance from regulatory authorities and professional organizations about how best to perform eye lens monitoring and use of eye protection would be welcomed. This will help to ensure optimization and harmonization of techniques across Europe during this important transitional period to adopting a reduced eye dose limit.

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