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Evaluation of the current status of the eye lens radiation exposure in an Interventional Radiology Department

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Parole chiave: Questionario; limite di dose al cristallino; dosimetri per il cristallino; radioprotezione

Summary

Background: *Following recent epidemiological studies, which showed tissue reactions from ionizing radiation at significantly lower doses, the 2013/59 EURATOM Directive of 5th December 2013 lowered the limit on the equivalent dose to the eye lens from 150 mSv to 20 mSv per year. Therefore, as a precautionary measure, it is considered appropriate to perform a timely dose monitoring by using specific dosimeters.* **Objectives**: *Analysis of the current state of the eye lens exposures during interventional procedures. The survey aimed at assessing the degree of information available to the exposed workers as regards lowering the dose limit in Interventional Radiology departments of some hospitals in Campania (Southern Italy).* **Methods**: *The equivalent dose was assessed, over a period of 90 days, using specific Hp dosimeters(3), placed sideways with regard to prescription eye glasses. The level of awareness of the new dose limit among operators was assessed using a questionnaire.* **Results**: *The values of the equivalent dose to the lens of the eye for the I and II Operators were found to be <150 mSv/year but for the I Operator a value of 54 mSv/year was obtained, ie higher than 20 mSv/year, that is the new limit of the equivalent dose according to 2013/59 EURATOM. The initial results of the questionnaire from 52 exposed workers, of which 46 (88%) were from exposure category A and 6 (12%) from category B, showed a low level of information (19%).* **Conclusions**: *The results highlight not only the importance of using specific devices for individual protection but also the importance of the level of training and information the exposed medical staff are given concerning the new regulations.*

Riassunto

«Valutazione dello stato attuale di esposizione alle radiazioni del cristallino in un reparto di Radiologia Interventistica». **Introduzione:** *In seguito a recenti studi epidemiologici i quali hanno mostrato reazioni tissutali da radiazioni ionizzanti, a dosi nettamente inferiori, la nuova Direttiva EURATOM 2013/59 del 5 Dicembre 2013 riduce il limite di dose equivalente al cristallino da 150 mSv a 20 mSv all'anno. Pertanto a scopo cautelativo si ritiene opportuno eseguire un monitoraggio puntuale della dose utilizzando dei dosimetri specifici.* **Obiettivi:** *Analisi sullo stato attuale delle esposizioni al cristallino durante le procedure interventistiche. Indagine mirata alla*

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valutazione del grado di informazione dei lavoratori esposti circa l'abbassamento del limite di dose nei reparti di Radiologia Interventistica di alcuni ospedali della Campania (Sud Italia). **Metodi:** *La dose equivalente è stata valutata, su un periodo di 90 giorni, utilizzando dei dosimetri specifici Hp(3), alloggiati lateralmente agli occhiali da vista. Successivamente è stata eseguita un'indagine sul grado di informazione degli operatori con l'impiego di un questionario.* **Risultati:** *I valori di dose equivalente al cristallino del I e del II operatore, sono risultati essere < di 150 mSv/anno ma per il I operatore è stato trova to un valore pari a 54 mSv, che è più alto dei 20 mSv/anno, che rappresenta il nuovo limite imposto dalla Direttiva EURATOM 2013/59. I primi risultati del questionario su 52 lavoratori esposti, di cui 46 (88%) di categoria A e 6 (12%) di categoria B hanno mostrato un grado di informazione basso (19%).* **Conclusioni:** *I risultati hanno evidenziato l'importanza dell'utilizzo di dispositivi specifici di protezione individuale e del grado di formazione ed informazione del personale medico esposto circa le nuove normative.*

Introduction

The increasing use of ionizing radiation in medicine, both for diagnostic and therapeutic purposes, has led to a review of the exposure threshold doses for both patients and medical staff. In this context, the 59/2013 EURATOM Directive (7) lays down the general principles for radiation protection, redefining the dose limits for occupational exposure in different categories of workers. Focusing our attention on exposed medical workers, the limit on the equivalent dose to the eye lens for these professional figures was re-defined, lowering it from 150 mSv per year to 20 mSv per year. As the eye lens is one of the most radiosensitive organs in the human body, its exposure to radiation may affect its integrity leading to the formation of lens opacities (11). Recent studies have shown that radiation-induced cataracts are not exclusively the result of high doses over a short period of time (1-3, 8, 15-17, 19). Nurses, technicians and, in particular, first and second operators working closely with the patient (which is the main source of diffuse radiation) are health personnel with high levels of occupational exposure to ionizing radiation. Up until now, the equivalent dose was estimated for a whole body by using the Martin formula (10).

It is important to estimate the eye lens dose with specific dosimeters. Up until now the measurement was made according to the Hp (10). The correlation between the eye lens dose and the Hp (10) measured over the apron has been investigated in various studies (11, 14). This correlation is affected by several variables like the beam quality, the angular response of the dosimeter, the operator position, the use of glasses and the position of non-structural shielding. All these variables provide a high dispersion in the relationship between these two magnitudes, but on average, the Hp (10) or Hp (0.07) tend to overestimate the dose for the eye lenses which can be interpreted as a conservative estimate (10,14). So the use of specific Hp eye lens dosimeters is important (3) so as to make a more accurate estimate of the equivalent dose, where 3 indicates the recommended depth for radiation which weakly penetrates the eye lens.

Aim of the study part

The aim of this article was to make a preliminary measurement of the eye lens dose and to gain information on the medical workers' knowledge as regards lowering the dose limit and especially on which devices for radiation protection were to be used. We have developed an ad hoc questionnaire which addresses some Interventional Radiology (IR) medical staff in Campania, in Southern Italy. The results of this study are reported in this work.

Methods

Ionizing radiation exposure assessment

Following the ICRP recommendations, the readings of Hp (10) or Hp (0.07) dosimeters, worn over the apron, were used to estimate the dose for eye lenses (in situations where no glasses were worn) (14).

They are LiF Mg, Cu, P thermoluminescence dosimeters and can be of different types depending on their use and positioning on the person. They are made by inserting the thermoluminescent sensitive element inside a card to which different filtrations are then applied depending on the measurement to be detected according to the positioning and, finally, the whole is inserted inside a polyethylene envelope to allow positioning sideways to both sight and screen glasses. These dosimeters are provided by TECNORAD, its characteristics are described in table 1. Hp (3) dosimeters were used to evaluate the eye lens equivalent dose in one of eight IRs (NA01), to obtain the preliminary results to compare with the estimated dose by whole body dosimeters.

The measurement of the eye lens equivalent dose was obtained by reading the Hp (3) dosimeters worn by the primary and secondary operators (I Operator and II Operator) of one of the Interventional Radiology located in Naples (code NA01). These devices were worn for a period of 90 days so those obtained are preliminary results. Operators placed dosimeters laterally to prescription eyeglasses during interventional procedures using a C-arm RX. In addition, so as to extrapolate the annual equivalent dose for the operator, we take into account their exposure dose during 2016.

Selection of the sample and collection of information

The questionnaire was designed by using closed structured questions, so that it could be answered without being overly time consuming and was aimed at exposed workers operating in the Interventional Radiology Departments of some important structures in Campania (Southern Italy). The Interventional Radiology structures have been assigned a code, i.e. NA01÷NA07 for the Interventional Radiology Units located in the city of Naples and CE01 for the Interventional Radiology unit located in the city of Caserta. Participants were reminded that the data would be used anonymously. An introductory letter was also provided on the web site to explain the main objective of the questionnaire. First of all, it was necessary to specify the exposure categories of the workers (A or B) according to the European legislation (6). The questionnaire was divided into three areas of interest, i.e. the first section investigates the knowledge of the changing of the eye lens dose limit for exposed staff. The second section was designed to establish the monitoring of the received doses, the type of dosimeters used, the position of

Table 1 - Performance of a TLD dosimeter for eye lens

Measured variables	Hp(3)
Detectors	LiF(Mg, Cu, P), GR-200A
Filtration:	1 mm ABS (about 20 mg/cm^2) for the determination of Hp(3) values
Response interval in energy (n):	Photons: 20 keV- 3 MeV;
Dependence of the response in terms of Hp(3) in the measured energy range:	<±25%
Dependence of the response in terms of Hp(3) as a function of the angle of incidence (max 60°):	<±15%
Minimal detectable dose (with 95% confidence in routine procedures):	Not more than 20 μSv;
Minimum certifiable dose (with 95% confidence in routine procedures):	Not more than 50 μSv;
More information	Symmetrical dosimeter. Dosimeter sterilizable according to procedures established by the Customer, with the only one precaution not to use temperatures above 60°C.

the dosimeters used for the evaluation of the eye lens dose, and the frequency with which it is followed. Finally, it was requested to specify the type of protection equipment used.

Results

Measurement of eye lens equivalent dose

For each Operator, data were acquired regarding the type of examination, the duration of the exam and some machine parameters (as shown in table 2). A total exposure time of 174 minutes for the first Operator and of 120 minutes for the second Operator, over the 90-day period was measured.

Dosimeter readings provided an equivalent dose in terms of Hp(3):

- I Operator: 2.16 mSv;
- II Operator: 0.30 mSv.

Because in 2016 the machine was used for 4330 minutes while over the 90-day period for 174 minutes (the work time of the first operator), by dividing the one-year work time by the 90-day period we can estimate the dose in one year as being:

- I Operator: (2.16·25=54) mSv/year;
- II Operator: (0.30·25=7.5) mSv/year.

To evaluate the differences between the exposure levels detected by the different dosimeters, the NA01 IR health Physics Service has provided whole body dose values of the two Operators obtained from Hp dosimeters (10), placed above the leaded aprons. These values are:

- I Operator: 0.48 mSv/year;
- II Operator: 0.66 mSv/year.

Using the Martin formula, we can obtain the dose for the eye lens by multiplying the value of the whole body worth dosimeter by 0.75 and it is therefore a dose equal to 0.36 mSv/year for the first Operator and 0.5 mSv/year for the second Operator.

Using a lens with a protection factor of 0.7, doses were:

- I Operator: 16.2 mSv/year;
- II Operator: 2.3 mSv/year.

The questionnaire

A total of 52 exposed workers were interviewed: 18 first Operators (operator-patient distance 0.5 m), 3 second Operators (operator-patient distance 1 m), 14 radiology technicians (TSRM), 14 Nurses, and 3 unclassified participants.

Classification of exposed workers

Table 3 shows the classification of exposure category (A and B) of the interviewed operators and their distribution by IR. Forty-six out of 52 workers (88%) were in exposure category A.

Table 2 - Summary sheet of diagnostic exams of I and II Operators with related times and machine parameters

Distance from the patient	Surgical interventions	Total running time	C-arm current	C-arm voltage
I Operator				
0.5 m	Nephrostomy	34 min	3 mA	90 kV
0.5 m	Hepatic biliary drainage	39 min	3 mA	(86-90) kV
0.5 m	Biliary stent replacement	15 min	3 mA	(86-90) kV
0.5 m	Selective arteriography with coaxial catheter	86 min	3 mA	86 kV
II Operator				
0.5 m/1 m	Nephrostomy	24 min	3 mA	90 kV
1 m	Hepatic biliary drainage	15 min	3 mA	(86-90) kV
0.5 m/1 m	Biliary stent replacement	66 min	3 mA	86 kV
0.5 m	Selective arteriography with coaxial catheter	15 min	3 mA	86 kV

Table 3 - Number of workers classified in A or B category stratified by Interventional Radiology Unit (IRU)

IRU	Category A	Category B
NA01	11	0
NA02	6	2
NA03	4	2
NA04	3	2
NA05	7	0
NA06	5	0
NA07	5	0
CE01	5	0
Total	46 (88%)	6 (12%)

Knowledge of the change of the dose limit to the eye lens

Nineteen per cent of the participants were aware of the change in the dose limit to the eye lens expected for 2018. Figure 1 shows the number of responses (Yes, No) given by the operators to the question on the knowledge of the new dose limit to the lens of the eye imposed by European legislation. The answers are reported for each IR.

Monitoring of dose to the eye lens and personal dosimetry

Figure 2 shows, for each IR, the number of operators for which the eye lens dosimetry was performed (twice a year), and the number of operators for which it was not carried out. Overall, the eye lens doses were estimated for 45 operators out of 52 (87%), while it was measured using the eye lens dosimeter every six months only for 7 operators out of 52 (13%).

All the exposed workers reported to wear individual dosimeters for the monitoring. Approximately 30 operators (56%) used the dosimeter for the extremities, while 15 (29%) the whole body dosimeters. In the latter group, only 5 wore the whole body dosimeter on the collar.

Positioning of dosimeters

As mentioned above, of the 52 respondents only 8 (15.4%) used the specific eye lens dosimeter. Of these 8, 5 claimed to place it near the eyes behind the weighted sunglasses, 2 said they placed the eyes in front of the leaded eyewear, and 1 claimed to wear a dosimeter on the collar.

Use of protective equipment and types

As regards protective equipment use and types (table 4), leaded coats and collars were used in most of the cases, 99% (51 out of 52) and 90% (47 out of 52) respectively. Only 44% of the cases wore protec-

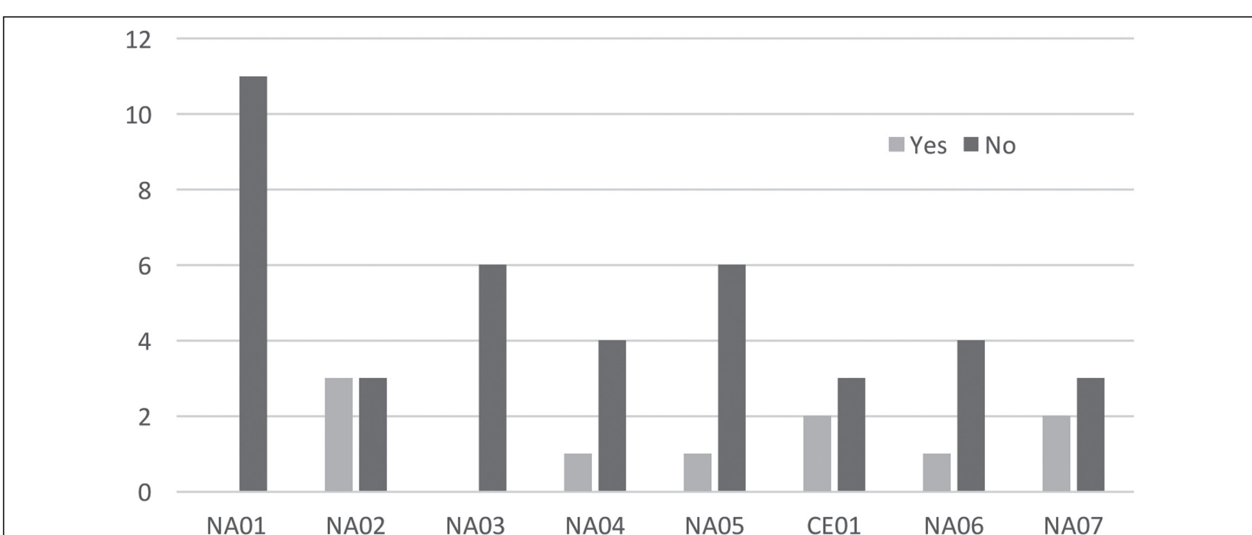

Figure 1 - Number of answers (Yes, No) given by the operators to the question on the knowledge of the new dose limit to the lens of the eye by Interventional Radiology unit

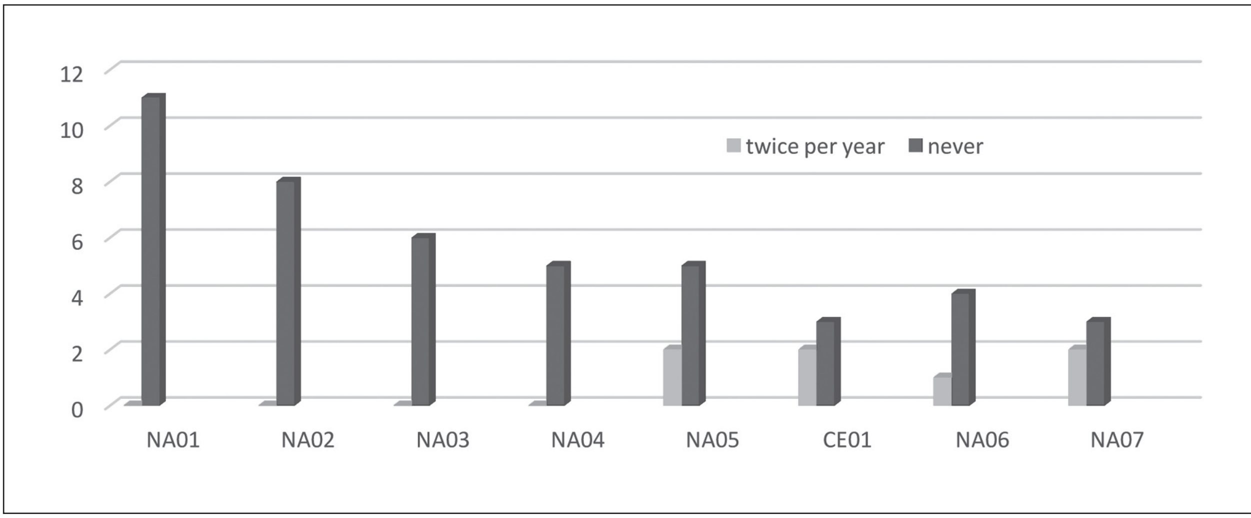

Figure 2 - Number of operators for which the eye lens dosimetry is performed (twice a year), and the number of operators for which it is not carried out (never) by Interventional Radiology unit

Table 4 - Use of protection equipment in the examined structures

Structures	Leaded coats	Collars	Glasses, masks, screens	Gloves
NA01	11	11	7	0
NA02	7	5	2	0
NA03	6	5	4	0
NA04	5	5	0	0
NA05	7	7	2	0
NA06	5	4	3	0
NA07	5	5	3	0
CE01	5	5	2	0
Total	51	47	23	0

tion lenses, such as glasses, masks and screens. None of the respondents referred the use of leaded gloves during the interventional procedures.

Out of a total of 23 workers who used eye protective equipment such as glasses, masks and screens, 57% were Operators, 26% Radiology Technicians and 17% Nurses.

Discussion and conclusions

In the framework of the 59/2013 EURATOM, the limit of the equivalent dose for eye lens will have a significant impact in the medical field, especially in interventional radiology and nuclear medicine.

Comparing the results obtained by using specific dosimeters Hp(3) with the limit currently in force, we can say that both operators (I and II) are exposed to a dose below 150 mSv per year (54 and 7.5 mSv/year respectively) but considering the new limit of 20 mSv per year that will come into effect in 2018 we can see that I Operator more than double exceeds the limit of the equivalent dose for eye lens.

We found discrepancies between the readings for Hp(3) dosimeters and the whole body dosimeter. It is possible that such inconsistencies derive from the failure or incorrect use of dosimeters. For this reason, the use of a simple personal protective equipment for the eyes, such as an anti-X lens, can greatly reduce the dose. Usually the lead composition of anti-X glasses varies, with an attenuation coefficient between 0.4 and 0.7.

The survey of some IRS in Campania (Southern Italy) shows that there is not a good level of awareness of the reduced eye lens dose limit. Many specific eye dose studies have already been carried out and the survey highlights that the new limit can be exceeded for Interventional Radiology workers. Guidance for professional organization and formation on how best to monitor eye lens and on the use of eye protection would be welcomed, as suggested by Ko et al (9). In particular, the use of lead glasses which fit the face well, appropriate lateral coverage, and/or ceiling suspended screens is recommended in workplaces with potential high eye lens doses, as reported in Ciraj-Bjelac et al (4).

The next step will be the study of the influence of the operator position, height and body orientation on eye lens doses, which are non- negligible factors (13).

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