

# Eye dose to staff involved in interventional and procedural fluoroscopy

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**Abstract.** In 2011 the International Commission on Radiological Protection (ICRP) lowered the occupational eye dose limit from 150 to 20 mSv/yr [1]. While international jurisdictions are in a process of adopting these substantial changes, medical physicists at the clinical level have been advising medical colleagues on specific situations based on dose measurements. Commissioned and calibrated TLDs mounted in commercially available holders designed to simulate the measurement of Hp(3), were applied to staff involved in x-ray procedures for a one month period. During this period clinical procedure data was concurrently collected and subject to audit. The use or not of eye personal protective equipment (PPE) was noted for all staff. Audits were conducted in the cardiac catheterisation laboratory, the interventional angiography rooms and the procedural room where endoscopic retrograde cholangiopancreatography (ERCP) procedures are performed. Significant levels of occupational dose were recorded in the cardiac and interventional procedures, with maximum reading exceeding the new limit for some interventional radiologists. No significant eye doses were measured for staff performing ERCP procedures. One outcome of the studies was increased use of eye PPE for operators of interventional equipment with increased availability also to nursing staff, when standing in close proximity to the patient during procedures.

## 1. Introduction

In 2011 the ICRP made a statement lowering the occupational eye dose limit from 150 to 20 mSv/yr [1]. This significant change resulted from new evidence of the risk of development of lens opacities or cataracts from studies with greater sensitivity and longer follow up periods to the initial studies [2]. Analysis by the International Atomic Energy Agency (IAEA) [3] has identified the implications of this change in dose limit as having the largest impact on occupational dose in the medical sector [4] for staff working in close proximity to patients undergoing fluoroscopically or CT guided interventional procedures, staff involved in preparation of sources or radiopharmaceuticals, or in manual brachytherapy and staff working with cyclotrons.

In response to this new understanding the monitoring of occupational dose has gained increased importance along with the established work of optimization of patient dose. The extent of occupational risk needs to be determined at each institution. In our hospital three audits of occupational eye dose have been undertaken so far, involving staff in Cardiac catheterization, Angiographic interventional studies and the Gastroenterology & Hepatology unit when performing ERCP procedures.

The clinical context for each of the above three audits was distinct, although all included medical staff, essentially the operators of the equipment and in close proximity to the irradiated area of the



patient, assisted by nursing staff who on occasion could also be close to the radiation field. Radiographic staff were in attendance (except in Cardiology) but typically remote from the radiation field, with anesthetic staff in attendance for the ERCPs, also remote from the radiation field.

A review of occupational dose results in the UK and elsewhere has been published for cardiac and angiographic procedures [5]. A number of reports on ERCP doses for both patients and staff, illustrating a wide range of determined eye doses have also been published [6-8]. The current work was then designed to determine the dose to the lens of the eye for occupational workers in the three environments and also to determine the eye dose per tube output, to assist in determining areas where dose could be reduced through a change in practice.

## 2. Methods and materials

### 2.1. TLD dosimetry

The dose to the lens of the eye was measured using TLDs of type-100H (Thermo Scientific, Ohio, USA) with dimension  $3.2 \times 3.2 \times 0.38 \text{ mm}^3$ , which were selected because of their good relative energy response in the diagnostic x-ray energy range and enhanced sensitivity (uncertainty of  $\pm 5\%$  from calibration energy). The TLDs were mounted in custom made holders (Eye-D™, RadCard, Krakow, Poland) that simulate the dose to the lens of the eye [9] designed for the measurement of Hp(3) doses [10]. Data from the manufacturers indicated that the relative angular response was extremely uniform (uncertainty of  $\pm 5\%$  from normal to  $80^\circ$  incidence).

The TLDs were commissioned under ISO 12794 [11] using a Harshaw 5500 TLD reader (Thermo Scientific, Ohio, U.S.A.). The TLDs were calibrated free in air outside of the holders through the use of TLDs reserved for calibration and background correction. The calibration beam was generated with a medium frequency x-ray generator at tube voltage of 80 kV with a measure half-value-layer of 4 mm Al. The x-ray equipment was under regular quality control to ensure its performance complies with the regulatory requirements. The dose to the lens of the eye was calculated using the following formula:

$$\text{Eye lens dose} = [\mu_{\text{en}}/\rho(\text{eye})/\mu_{\text{en}}/\rho(\text{air})] \text{RER} \cdot k \cdot M$$

where RER is the relative energy response (held to unity),  $k$  is the TLD calibration factor, and  $M$  is the background subtracted TLD reading. Mass energy absorption coefficients [12] were for the effective energy of the calibrating beam. The associated uncertainty, taking into account the relative energy and angular response, the mass energy absorption coefficient variation across the possible energy range and TLD reading accuracy was estimated to be about 10% for readings above 1 mSv and about 14% for reading just above background levels.

### 2.2. Clinical measurement and data collection

For each of the three clinical environments (table 1) where eye dose measurements were made the same methodology was used. Each staff member present in the room during a fluoroscopic procedure was assigned an individual eye holder that was attached to an elastic head band, which allowed the eye holder to be placed near the corner of the left eye and outside the protection of the lead glasses if worn. This positioning was ascertained to typically receive the maximum dose.

**Table 1.** Clinical environments investigated.

Clinical situation	No. staff involved	procedures	average KAP (Gycm <sup>2</sup> )	average procedure time (min)	No. X-ray units
Cardiac laboratory	17	192	34.8	32.8	2
Angiography Suite	18	93	242.3	67.9	2
ERCP procedures	14	34	5	20	1

The measurements were made over a one month period at each location. During this time, reference data was collected; including patient data such as age, height, weight; radiographic factors

such as the tube output in terms of kerma area product (KAP) and cumulative air kerma (CAK), as well as the staff present for each procedure, their duty and location and whether they wore lead glasses to protect their eyes. This data was gathered for each procedure under the scrutiny of each laboratory coordinator before final review of data integrity.

### 2.3. Data analysis

For each clinical environment the staff's use of protective lead glasses and workload data was established by analysis of each staff member to determine the number of procedures they had been present for and also the cumulative KAP value for those particular procedures. The proportion of the total tube output that staff was protected by lead glasses was calculated. Further the measured eye doses were normalized by the cumulative KAP to give the eye dose rate for each individual.

## 3. Results

Analysis of the collected data revealed a significant spread in the eye doses received by staff within and also between clinical environments as seen in table 2. It was noted in cardiology that there were 2 consultants with recorded eye doses at 50% of the ICRP recommended limit. However the eye doses in angiography were of a higher magnitude, with three medial consultants having eye doses in excess of the ICRP limit (figure 1), requiring a report to be made to the local regulators. The doses in ERCP were low as is consistent with the nature of the radiation exposure used by this environment as seen in table 1.

**Table 2.** Statistical breakdown of the extrapolated annual eye dose (mGy) for both medical staff and nurses in each of the clinical environments.

	Cardiology		Angiography		ERCP	
	medical	nurse	medical	nurse	medical	nurse
minimum	0.68	0.49	2.40	0.65	0.21	0.17
1st quartile	1.41	0.78	12.16	1.13	0.30	0.18
median	1.54	1.32	18.05	6.06	0.37	0.21
3rd quartile	4.45	2.59	<b>26.55</b>	7.39	1.00	0.35
maximum	9.64	3.09	<b>59.01</b>	14.88	2.77	0.46

The cumulative protection from lead glasses to staff for each environment was 50% in cardiology, 30% in angiography and nil for ECRP procedures. The rate of eye dose as a function of tube output, as seen in Table 3, again showed a marked difference between the clinical environments. Of interest the readings from ERCP are the highest, despite the fact that these staff experienced the lowest total doses.

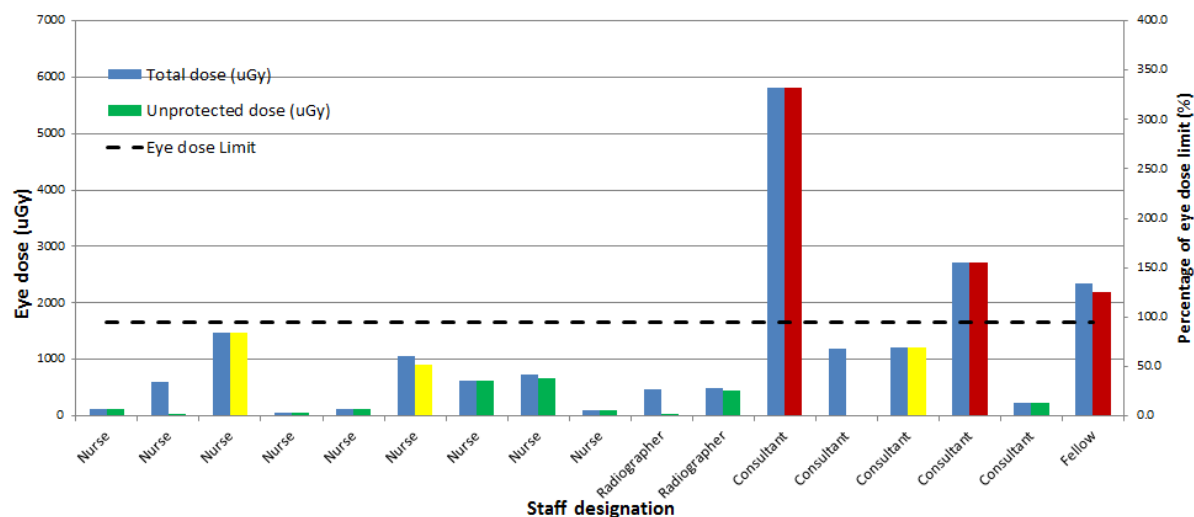
**Table 3.** Statistical breakdown of the eye dose/KAP ( $\mu\text{Gy}/\text{Gycm}^2$ ) for both medical staff and nurses in each of the clinical environments

	Cardiology		Angiography		ERCP	
	medical	nurse	medical	nurse	medical	nurse
minimum	0.13	0.05	0.19	0.04	0.96	0.26
1st quartile	0.25	0.08	0.56	0.06	1.24	0.29
median	0.34	0.13	0.93	0.10	1.51	0.36
3rd quartile	0.43	0.18	1.64	0.19	1.90	0.40
maximum	0.56	0.23	2.04	0.48	1.51	0.61

## 4. Discussion

The audits revealed that for each of the clinical environments, that the use of protective glasses was not thought a high priority. However, McVey *et al.* [13] have shown that the wearing of correctly

fitted leaded glasses reduces dose to the eye by approximately 80%. In the case of the angiographic suite Figure 1 clearly demonstrates staff members that measured as over 50% (yellow) and 100% (red) of the ICRP limit. Staff awareness of this data has resulted in the almost universal wearing of lead glasses in this environment.



**Figure 1.** Range of eye doses measured over one month for the Angiography Suite.

Upon review of the audit results a number of components critical to dose reduction were identified. Comparison of typical tube output for similar procedure types in cardiology revealed that the older of the two x-ray units on average used 40% more radiation dose that would be expected to contribute directly to a similar increase in eye dose. This unit has subsequently been replaced and a recent dose audits reveals the new unit is operating at considerably lower dose to that of the previous units.

Conduct of the procedure has also been found to have a significant impact of occupational dose. It was noted that in some procedures that staff maintained positions very close to the patient during acquisition runs. While this might be considered necessary in some cases, the use of continuous collar radiation monitors (Rad Safe i2) has demonstrated real time the importance of considering the proximity to the patient in scatter dosage and as appropriate the importance of properly utilising protective lead glass screens. Further study is planned to quantify changes in eye dose due to heightened staff awareness.

One surprise of the audits was the relatively high dose rate found in ERCP. It must be stressed that the actual eye dose levels were low, however when normalised with tube output, there were indications that some changes in practice might be useful. It was further noted that in the room used for ERCP there is not overhead moveable shield available, which might have contributed to higher eye dose per tube output. It should be noted that the configuration of the room, utilising under table tube, was otherwise consistent with best practice [6].

One important outcome of the work was the realisation that nursing staff, while not the closest to the radiation source, often are present for a large number of procedures. Often they also may be in close proximity to the patient, but without the additional protection of a mobile lead screen. As seen in Figure 1 three of the highest six eye dose measurements in angiography were received by nurses. For this reason changes have been made to the relevant radiation management plans to ensure provision of lead glasses for nurses, should they elect to wear them during procedures.

## 5. Conclusion

The use of TLD dosimetry in combination with well-designed TLD holders that allow acceptable clinical implementation, can add substantially to knowledge on staff eye dose due to high dose rate fluoroscopy. The three audits undertaken had a number of beneficial outcomes on clinical practice, including the increased usage of lead glasses, examination of procedural technique to reduce both

patient and staff dose, and a recognition that nursing staff need to be considered when assessing risk to the eyes from x-ray exposure during fluoroscopy.

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