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SHORT COMMUNICATION

Eye dose monitoring of PET/CT workers

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Objective: The objective of the study was to measure eye dose [Hp(3)] to workers in a busy positron emission tomography (PET)/CT centre. Doses were compared with the proposed new annual dose limit of 20 mSv.

Methods: We used a newly designed dosimeter to measure eye dose [Hp(3)]. Eye dosimeters were worn with an adjustable headband, with the dosimeter positioned adjacent to the left eye. The whole-body dose was also recorded using electronic personal dosimeter (EPD® Mk2; Thermo Electron Corporation, Waltham, MA). Exposed staff included radiographers, nurses and healthcare assistants.

Results: The radiographers received the highest exposure of the staff groups studied, with one radiographer receiving an exposure of 0.5 mSv over the 3-month survey period. The estimated maximum eye dose for 1

year is approximately 2 mSv. The numeric value for eye dose was compared with the numeric value for personal dose equivalent to see if one could be used as an indicator for the other. From our data, a conservative estimate of eye dose Hp(3) (mSv) can be made as being up to approximately twice the numeric value for whole-body dose [Hp(10)] (mSv).

Conclusion: Eye dose was found to be well within the new proposed annual limit at our PET/CT centre. Routine whole-body dose measurements may be a useful starting point for assessing whether eye dose monitoring should be prioritized in a PET facility.

Advances in knowledge: Following the proposal of a reduced eye dose limit, this article provides new measurement data on staff eye doses for PET/CT workers.

In 2011, the International Commission on Radiological Protection (ICRP) published a statement on tissue reactions, which recommended reducing the annual equivalent dose limit for the lens of the eye from 150 to 20 mSv.¹ The reduced limit—based on new evidence suggesting a threshold in absorbed dose for radiation-induced cataracts of 0.5 Gy—is <15% of the previous limit, and its proposal has led to considerable debate in the literature.^{2–4}

With the lower eye dose limits having now been adopted in the new EU directive,⁵ the discussion has progressed to include consideration of which type of occupational roles are likely to require routine personal monitoring for eye dose. The directive must be transposed into the national legislation by EU member states within a period of 4 years. This places a considerable onus on centres to assess eye dose, and this brings with it a need for improved eye lens dose monitoring.⁶

Hp(3) is the personal dose equivalent at a depth of 3 mm in soft tissue and is used for measuring lens dose. In this study we used a newly designed dosimeter^{7–9} to measure eye dose in terms of Hp(3) in a busy positron emission

tomography (PET)/CT centre. PET is a relatively high patient dose modality with the potential to give high staff doses. Although there is a lack of data on typical eye dose to PET workers, whole-body and hand doses are both higher than in other types of nuclear medicine services.¹⁰ As such, PET is an obvious candidate for eye dose studies. In this study we measured eye dose to PET staff to assess whether the new eye dose limit might be reached. As eye dose monitoring is not performed routinely, we were also interested in whether it was possible to estimate staff eye dose from whole-body dose measurements.

METHODS AND MATERIALS

The study was conducted in a purpose-built, modern PET/CT centre housing a Discovery VCT PET/CT scanner (GE Healthcare). The typical workload during the period of the survey was 11 patients per day. The PET/CT system is used primarily for oncology scanning with 360 MBq of fluorine-18 fludeoxyglucose administered as standard; a small number of brain scans (<5% of the total scans) were also performed with 200 MBq administered. Activity was administered 1 h prior to scanning. The centre has four shielded injection bays that are linked by a corridor to the scanning room.

Access to patient toilets is also off this corridor. Staff explain the procedure to the patients prior to administration of the radioisotope.

Exposed staff included radiographers, nurses, healthcare assistants (HCAs) and a medical physicist. Interaction with patients after injection is guided by clinical need. The nurses' interaction with patients is usually prior to administration of the radioisotope, but nursing staff are available for assistance with patients as needed. The HCAs have limited interaction with patients; duties may include bringing tea or coffee to patients after the scan has been completed. Patients are escorted to and from the scanner by radiography staff. The physicist and radiography staff provide radio pharmacy support, including loading vials (provided by an off-site cyclotron) and drawing up injections. The pharmacy work area is surrounded by a castle of lead (Pb) blocks, with a 50-mm Pb equivalent viewing window. Injections are held in 5-mm Pb syringe shields and transported to the injection bay in a shielded trolley. Radiation protection practices for staff were well established when this survey was conducted, and no further practice change was introduced specifically for eye dose. Workers did not wear protective shielding or glasses. Five radiographers worked in the PET/CT centre over the period of the study, with up to three being present on any one day.

Personal monitoring with whole-body passive dosimeters is already carried out in the PET/CT facility in accordance with the Irish legal requirements.¹¹ Staff wear whole-body thermoluminescent dosimeters (TLDs) and finger badges and, in addition, carry electronic personal dosimeters (EPD® Mk2; Thermo Electron Corporation) to record their daily whole-body [Hp (10)] personal dose equivalent. EPDs are calibrated annually. Radiographers have the highest whole-body doses of the groups working in the PET/CT centre.

In addition to the personal monitoring described above, a dedicated eye lens dosimeter (EYE-D™, RADCARD, Krakow, Poland) was issued to staff who were participating in this study. The EYE-D was developed as part of the EU optimization of radiation protection for medical staff (ORAMED) project specifically to measure Hp(3). The EYE-D unit consists of a TLD pellet and a plastic (polymide) capsule. The supply, calibration and readout of the EYE-D dosimeters were performed in the laboratory at RADCARD in Poland prior to being shipped to Ireland. Calibration was performed using the newly developed cylindrical phantom, which is more representative of the head.⁹

Eye dosimeters were worn with an adjustable headband that is provided by the EYE-D supplier, with the dosimeter positioned adjacent to the left eye. The radiographers and the medical physicist were assigned individual eye dosimeters. Only one nurse or HCA was assigned to the PET/CT centre on any one day, and the eye dosimeters for the HCA and the nurse were shared among staff fulfilling this role. Eye dosimeters were stored in the PET/CT control room when not in use. Staff were reminded to only wear the eye dosimeters during PET/CT clinics and as such no account was taken of eye dose received from other areas of radiology. The monitoring period was 91 days, after which all dosimeters (including unirradiated transport dosimeters) were returned to RADCARD in Poland to be read out.

RESULTS

Measurement data are summarized in [Table 1](#).

As expected, the radiographers received the highest exposure of the staff groups studied, with one radiographer receiving an exposure of 0.5 mSv over the survey period. The exposure to nurses and HCAs was comparatively low, and as these measurements were for the role rather than an individual, the actual exposure to a nurse or HCA will be some fraction of this dose.

Table 1. Measured eye dose Hp(3) for survey period and estimate of annual dose

Staff occupation	Measurement of eye dose Hp(3) (mSv) for survey period	Estimate of annual eye dose Hp(3) (mSv)
Healthcare assistant	0.02	0.08
Nurse	0.01	0.04
Physicist	0.01	0.04
R1	0.42	1.68
R2	0.04	0.16
R3	0.50	2.01
R4	0.27	1.08
R5	0.47	1.89
Average	0.22	0.87
Maximum	0.50	2.01
Minimum	0.01	0.04

R, radiographer.

Table 2. Comparison between numeric values for Hp(3) and Hp(10)

Staff	Days EPD worn (<i>n</i>)	Hp(3) (mSv) for survey period	Hp(10) (mSv) for survey period	Percentage difference
R1	42	0.42	0.46	−8
R2	31	0.04	0.27	−86
R3	40	0.50	0.45	+11
R4	20	0.27	0.19	+44
R5	31	0.47	0.30	+54

EPD, electronic personal dosimeter (EPD® Mk2; Thermo Electron Corporation, Waltham, MA); R, radiographer.

As whole-body doses for this group are also very low, the low eye dose recorded in this survey accords with expectation.

Owing to staff rotation, staff were not present for all working days during the survey. The number of days worked for radiographers are shown in Table 2. If we assume that the survey period was sufficiently long to provide a representative snapshot of working patterns and exposure during the year, then estimated yearly dose may be calculated. This assumption is likely to hold for the HCA, nursing and radiographer roles, which follow a well-defined pattern. In the case of the medical physicist, eye dose is unlikely to represent the yearly dose, as the main exposure occurs during annual quality assurance tasks, which did not take place during the monitoring period.

The higher exposure to radiographers reflects occupational exposure patterns, with radiographers involved in radio pharmacy work, administration of the isotope and conducting patients through the scan process. Factoring up to annual exposures, the estimated maximum eye dose for 1 year is approximately 2 mSv. This is considerably lower than either the proposed dose limit of 20 mSv or the threshold for classifying a worker as category A of 15 mSv.

Eye dose monitoring is not performed routinely, and we were also interested in whether an estimate of eye dose could be made from whole-body dose measurements. Hp(3) and Hp(10) are different dose quantities, and the dosimeters are worn at different positions—waist level for Hp(10) and at the left eye for Hp(3). However, basic relationships such as an increase in the level of exposure resulting in both dose measurements increasing and a decrease in the level of exposure resulting in both dose measurements decreasing can be expected. Table 2 compares doses measured using the eye dose badge with doses measured with EPDs for the survey period. For four of the radiographers in the group, the numeric value of eye dose was within approximately 50% of the numeric value of the whole-body dose. For radiographer 2, the dose recorded for the eye badge is much lower than the whole-body dose. The exposure situation is such that exposure to both the body and head occur with each patient encounter. As the eye dose is much lower than the dose recorded at body level (when in general, the eye dose numeric value was higher), the data strongly suggest that

radiographer compliance in wearing the eye badge was poor in this case. The practice of wearing EPDs is well established in the PET/CT centre and compliance among the radiographer staff very good.

Although the dose quantity for personal dose equivalent and eye dose are different, knowing the numeric value for Hp(10)—which is measured routinely in a PET/CT centre—appears to give us an indication of what the eye dose is likely to be. If we take the data from radiographers 1 and 3–5, a conservative estimate of eye dose Hp(3) (mSv) can be made as being up to approximately 1.5 times the value for personal dose equivalent. Thus, if measurements for staff Hp(10) are <2 mSv, we might estimate eye dose as 3 mSv and have a high degree of confidence that the eye dose does not exceed 15 mSv. In applying this approach to higher staff doses, or to other PET/CT sites, it would be prudent to increase the margin of error to allow for non-linearities, or site-specific differences. For example, if, as a rule of thumb, we were to use double the numeric value for personal dose equivalent Hp(10) as a broad, initial estimate of eye dose, this might serve as a useful starting point in assessing whether prioritizing eye dose monitoring at a PET/CT facility is appropriate. This relationship between values for the two quantities also suggests that workers are likely to become category A workers based on whole-body exposure (of 6 mSv), before reaching the category A level of 15 mSv for eye dose. As eye dose measurement in PET is relatively new, further studies at facilities with different room design, staff compliment, work practices or measurement methods (e.g. differences in measurement equipment/meter positioning) would also be of value.

CONCLUSIONS

Eye dose was found to be well within the new ICRP and EU limit at our PET/CT centre. The numeric value for Hp(3) was within approximately 50% of the numeric value for Hp(10) in our study. As such, applying an appropriate factor to whole-body dose measurements may be a useful starting point in assessing whether eye dose monitoring should be prioritized in a PET/CT facility.

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