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Personnel dosimetry in UK radiology: is it time for a change?

Radiology department staff wear lead/rubber aprons when working in x-ray controlled areas and these protect the trunk and thighs from radiation exposure. Such aprons contain the equivalent of 0.25 mm or 0.35 mm thickness of lead and so reduce the exposure of radiosensitive organs in the trunk by a factor of ten or more. The UK approach to personnel dose monitoring in radiology has been to wear a dosimeter under the lead apron, to provide a measurement of the dose to the protected organs which it is argued will be closely related to effective dose. Interventional radiologists and interventional cardiologists with heavy workloads may wear a second dosimeter at their collar outside the lead apron. This will record the dose to the head and the thyroid if it is not shielded by a protective collar. This double-dosimeter methodology is the approach currently recommended by the International Commission on Radiological Protection for those undertaking interventional procedures (ICRP 2000).

The information that a dosimeter worn under a lead apron provides to radiation protection personnel is limited. The dosimeters worn by the vast majority of radiology staff never register a reading and even the doses recorded by interventional radiologists and cardiologists are usually less than 0.2 mSv per month. Since these doses recorded are comparatively close to the recording threshold, they do not provide data that are sufficiently reliable to form the foundation of a rigorous dose optimisation strategy. Thus the main function that the dosimeter serves is to provide the apparent reassurance that staff doses are well below the dose limit for the body. However, there are considerable uncertainties as compliance in the wearing of dosimeters is often difficult to achieve among interventional clinicians who are focused on the procedure in hand which can often be a matter of life or death for the patient. A dosimeter under an apron is not visible to other staff, so it is not apparent when a dosimeter is not worn or is positioned incorrectly, thus checking dosimeter compliance can be problematic.

The proposal to reduce the dose limit to the eye, whether to 20 mSv (ICRP 2011) or 50 mSv places a different perspective on dose monitoring. There will almost certainly be a dose constraint of 15 mSv to the eye with which all non-classified radiation workers should comply and this limit is more likely to be exceeded than that for the body. Therefore it is logical that when a single dosimeter is worn, this should be at the collar outside the lead apron, and be used as a measure of the dose to the eye. Results from various studies have shown that in practice this dose is similar to or slightly more than the dose to the eye (Martin 2009). The Health Protection Agency now have a dosimeter that can be worn at the collar, calibrated and approved to measure the personal dose equivalent at a depth in tissue of 3 mm \( H_{p}(3) \), the quantity recommended for use in assessing the dose to the crystalline lens of the eye.

Many radiation protection experts in other parts of the world argue that wearing a single dosimeter under the lead apron, even if the dosimeter is positioned correctly, does not provide a realistic assessment of the effective dose. If no protection for the thyroid is worn, then contributions from the doses to the thyroid and head will more than double the actual effective dose to the individual (Martin 2009). In addition, the doses to the thorax received through the unprotected armholes can be significant for exposures from the side in orientations similar to...
those encountered in interventional radiology (Franken 2002). For whole body monitoring, international opinion is divided on whether, when a single dosimeter is worn, it should be under the lead apron or outside it. The UK has led the way in promoting the under-apron dosimeter method, but many countries are critical of this approach and see little value in monitoring the organs that are protected, while ignoring the doses to those that are exposed directly. For instance, the National Council on Radiation Protection and Measurements (NCRP), who set out the recommended practice for the United States of America, states that ‘a single personal dosimeter worn at neck level above protective garments may be used in the fluoroscopically guided interventional procedure environment’. Although they recommend the two dosimeter approach described earlier for those who may receive more significant exposure (NCRP 2011). This document states explicitly that ‘a single dosimeter worn under radiation protective garments is unacceptable because it provides no information about eye radiation, and would not account for contributions to the effective dose from irradiation of organs or tissues not covered by a protective garment (e.g. the thyroid if no thyroid shield is worn)’. Other countries that follow a similar approach include the Netherlands (NCRD 2008) and Norway (Lie et al 2008) and a survey of dosimetry practices in radiology found that the approach taken in five out of 13 European countries contacted was to wear a single dosimeter at the collar outside the lead apron (Jarvinen et al 2008a).

There are several drawbacks in using a single dosimeter under the lead apron as the first monitoring option in radiology. The potential lowering of the eye dose limit tips the balance in favour of an approach in which, the first (and possibly only) dosimeter to be worn is positioned at the collar outside the lead apron to record the dose to the eye. This has a number of advantages:

- The dosimeter reading can be used directly to provide a measure of eye dose in terms of either the $H_{p}(3)$ or $H_{p}(0.07)$ value recorded.
- Compliance in correct wearing of the visible dosimeter can more readily be confirmed by the attendant radiographer, who will often be the Radiation Protection Supervisor.
- The $H_{p}(10)$ reading provides an indication of the dose level in the interventional room.
- The dose levels recorded will be sufficiently large to allow a definitive strategy for dose monitoring to be developed in the given situation.

The continual increase in the amount of interventional radiology and cardiology work undertaken, coupled with difficulties in gaining compliance in the wearing of dosimeters by interventional clinicians requires a more co-ordinated approach to personnel dosimetry. If the first dosimeter were worn outside the lead apron to monitor eye dose, then dose ranges that might be expected could be more readily established and investigations carried out if dose levels were either above the expected range, due to poor practice, or below it, perhaps due to poor compliance in wearing dosimeters. If the $H_{p}(10)$ recorded for the year exceeded 10 mSv, then the individuals could be asked to wear a second dosimeter underneath the lead apron. However, this in itself has limited value, as years of accumulated dosimetry data have shown that the dose recorded by a dosimeter worn under the lead apron is unlikely to approach the effective dose limit. Therefore a realistic estimate of effective dose can only be obtained by combining the under apron dose measurement with that above the apron to account for the dose to unprotected organs using an agreed, suitable formula.

The $H_{p}(10)$ recorded by a dosimeter outside the lead apron will inevitably give an overestimate of the effective dose and so cannot be used directly for this purpose, but this is secondary to the need to record the eye lens dose. However, it could potentially be used in the future as an indicator of effective dose if a conversion factor is agreed. For example, the Netherlands divide the $H_{p}(10)$ value by five to derive an estimate of effective dose (NCRD...
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2008). A factor in the region of five or 10 would be appropriate but would have to be agreed nationally. Although the practice of applying correction factors to personnel dosimetry measurements has not been adopted previously in the UK, any dosimeters used for assessment of the dose to the eye are unlikely to be worn under the protective eyewear by the interventional radiologists or cardiologists, so a correction will need to be applied to account for additional protection of the eye. Studies show that such eyewear reduces the dose to the eye by factors of between three and eight (Vanhavere et al 2011, Geber et al 2011), so the eye-dose reading recorded should be divided by a factor of at least three where protective goggles are used. Therefore, the principle of making adjustments to the dosimeter reading to take account of the use of personal protective equipment should be introduced, to allow assessment of doses to both the body and the eye and these factors should be agreed across the UK.

The use of a two-dosimeter monitoring system is more complicated in practice and requires the use of a formula linking the two doses, of which there is a plethora of examples in the literature (Clerinx et al 2008, Jarvinen et al 2008b), to derive a more realistic assessment of effective dose. Such adjustments have not so far been favoured in the UK, but the proposed change in dose limit for the eye requires a review of dose monitoring practice and consideration should be given to these options for the future.

Thus it is perhaps time for the UK to change the approach to dose monitoring for interventional radiology, interventional cardiology and even for other radiology staff, so that when a single dosimeter is used, it is worn at the collar outside the lead rubber apron to provide a record of eye dose, and this value is divided by a UK agreed factor (e.g. 5) to record the estimate of body dose that is required by the regulations. The information could also be used to promote a more proactive approach to personnel dosimetry. Requirements for wearing a second dosimeter could be based on monitoring results for the collar dosimeter and, if this exceeded an agreed level in a single year (or less), then a second dosimeter might be made mandatory in subsequent years. It is acknowledged that double dosimeter monitoring for all interventional radiologists and cardiologists is the ideal, but with constraints imposed by both achieving compliance in wearing dosimeters by interventional clinicians and keeping within NHS budgets, this is difficult to attain and enforce, except where doses can be demonstrated to be high. Moreover, without an agreed formula for utilising the results of the two dosimeters, the value is limited. The switch to the proposed approach of wearing the first (and maybe only) dosimeter above the lead apron to record eye dose specifically, may help staff to improve compliance in wearing dosimeters through visibility, and enable a more systematic strategy to be developed based on the higher dose levels recorded.

References


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