Mobile CT Shielding – invited talk

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CT scanner facility shielding is very important to ensure the radiation exposure of employees and members of the public is as low as reasonably practicable. Due to the high dose rates and cumulative exposure at a CT scan room shielded barrier, any missing shielding can lead to overexposures, under the Ionising Radiations Regulations 2017, within a matter of weeks. A complete critical examination of barriers is essential. There is the potential for shielding engineering controls to fail during transport of mobile CT scanner facilities. There is also the potential for shielded barriers to be replaced with non-shielded barriers throughout the lifetime of a scanner facility. This talk shares methods and learning from physicist CT van barrier assessment projects and the weaknesses identified. A review of resultant radiation incidents leads to a rethink of the radiation risk assessment and mitigation measures to ensure dose limits are never exceeded.

Cardiovascular and cerebrovascular effects of radiation exposure. Should we be concerned?

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An increased risk of cardiovascular and cerebrovascular disease from radiation exposure was first observed in data from the Life Span Study cohort of the Japanese atomic bomb survivors (4,5). They exhibited excess relative risks for both heart disease and stroke that increased with dose. In addition, risks of cardiovascular disease have been increased by several fold in patients treated with radiotherapy for cancers in the thorax in the past. Clear trends in increasing risk of cardiovascular diseases with dose to the heart can be seen in patients treated with radiotherapy for breast cancer (7) and Hodgkin lymphoma (8). An increased incidence of cardiovascular disease with heart dose is also seen among child patients treated with radiotherapy in a large US study (6), but with improved limitation of irradiation of surrounding tissues during treatment delivery, incidence rates are gradually declining. Direct evidence of any effects from low radiotherapy doses (<100 mSv) is limited, and can only be inferred from extrapolation of risks from higher received doses.

Based on the evidence available, ICRP 118 concluded that there are excess risks of heart disease for individuals that receive heart doses of 1–2 Gy with the excess risks becoming apparent 10–20 y after exposure, and a similar risk of cerebrovascular effects from exposure of the head (3). Following on from the concern raised, cohort studies have been carried out on other populations irradiated through accidental or occupational total-body exposures. Raised incidences of cerebrovascular and cardiovascular disease have been reported among workers at the Russian Mayak nuclear plant who received cumulative doses up to 2 Gy (1). Relationships between the risk of circulatory disease and radiation dose extending down to 100 mGy have also been reported among workers in nuclear establishments in the UK, USA and France (2), and the UK national registry for radiation workers shows a link between cumulative dose and mortality from ischaemic heart disease (1). However, there is substantial variation in the association between radiation exposure and circulatory disease in different studies and between workers at different facilities. The jury is still out on whether risks of circulatory disease extend to occupational dose levels received by radiation workers.

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Pass/fail criteria for leak tests – what constitutes a fail, and how should that be managed?
Emma Birch, The Christie NHS Foundation Trust

Background: IRR17 requires sealed sources to be leak tested at intervals not exceeding 2 years, and sealed source Permits require notification to the Environment Agency if sealed sources are damaged. New sources are leak tested by manufacturers, so further leak testing is not required until the source is 2 years old. Christie standard practice is to leak test all new sources upon receipt. Recently activity was detected on a leak test from a new Cs-137 source.

Methods: Small amounts of long-lived activity were found on the swab. The source was taken out of use pending further investigation and the Environment Agency was informed of a potentially damaged source. Multiple additional swabs were taken of the source and the inside of its container.

Results: All subsequent swabs were negative for activity. On that basis we judged that it was highly unlikely that the source was leaking, and it was returned to use.

Discussion: Following the incident the legal requirements for leak tests, including pass/fail criteria were reviewed. The IRR17 Approved Code of Practice states that leak tests must have clearly defined pass/fail criteria but gives no guidance on what these should be. Manufacturers are working to ISO 9978:2020 recommendations, which state that wipe tests are only considered a fail >200Bq. It therefore cannot be guaranteed that new sources are 100% free from contamination.

A risk assessment was performed to justify use of sources before the end user's initial leak test results are received. This included assessments of potential skin and ingestion doses from up to 200Bq contamination. A proposed approach for management of new sources and leak test results was devised.

Conclusion: Our proposed approach is as follows:

End users should perform leak tests on new sources as soon as reasonably possible after taking receipt. Sources may be put into use immediately, but until the leak test results are received to confirm an absence of removeable activity, steps should be taken to prevent potential contamination (handle using gloves etc.).

Results that are non-zero but <200Bq should be considered indeterminate. The source may continue to be used (with precautionary measures in place) while further investigation is ongoing to determine the source of the activity.

Results ≥200Bq should be considered a fail. The source should be removed from use and the Environment Agency notified within 24 hours of the fail result being received. If leaked activity is thought to be above the relevant threshold in IRR17 Schedule 7, the HSE must also be notified.

Key references: Sealed sources, leak tests

Title of Study: Experience with identifying and rectifying raised radiation dose outside a Controlled Area through environmental audit

Elizabeth Bennett – Lead Clinical Scientist Nuclear Medicine, NCIC

Background. Regulation 20(1-2) of the Ionising Radiation Regulations 2017 stipulates a need for area monitoring where an employer has designated Controlled or Supervised Areas. The Approved Code of Practice Guidance to this provides for this monitoring to include measurements made at the boundaries of such areas. We offer a case study of routine boundary monitoring carried out at the Cumberland Infirmary during 2021 that highlighted a failure in control methods.

Methods. Luxel dosimeters were placed at the boundaries of the Controlled area associated with the Cumberland Infirmary Radiopharmacy between 26th July 2021 and 8th September 2021. Where the boundary corresponded to an exterior wall of the building double overwrapping in ziplock bags was used to protect the badges during monitoring and Gorilla tape was used to affix these badges to the exterior of the building in a manner that proved resilient against the Cumbrian weather.

Results were provided by the dosimetry service based on an 8 hour working day as a time averaged dose rate and as an extrapolated annual dose.

Results.

Location	Measured TADR (µSv/hr)	Extrapolated annual dose (mSv)
Aseptic suite to corrridor (door)	0.52	1.08
Collation to corridor	0.60	1.24
Collation to control	1.67	3.48
Exterior wall to collation	0.36	0.75
Exterior wall to aseptic	1.95	4.06
Unused clean room to aseptic	0.44	0.91
Loft above collation	0.36	0.75
Loft above aseptic	0.32	0.66

Discussion. The extrapolated annual dose at the exterior wall to the aseptic suite was an immediate cause for concern since this area lies outside the nuclear medicine department and at the time of monitoring was not subject to any access control.

Investigation showed that the total exterior envelope of the building at this point was a single glazed window and a sheet of plywood, providing little to no shielding and aligned with the Mo99/Tc99m generator cabinet.

Initially a Supervised area was established and a short system of work produced that directed staff using this area to use it only for transit. The intention was to ensure a low occupancy factor to maintain acceptable levels of exposure. This was favoured over engineering controls as initial advice from PFI maintenance and Estates was that bricking up the window and/or installing additional shielding may cause damage to the clean room itself, which was in daily use.

At a subsequent HSE inspection this was deemed inadequate and a review of the risk assessment led to an additional brick skin and shielding being added without removal of the window to assure both radiation protection and clean room integrity objectives. A repeat monitoring study is currently underway to confirm successful dose reduction (results will be available for presentation).

Conclusion. Routine environmental monitoring demonstrated its usefulness as a safeguard against evolving use of a space and changes in practice posing an unrecognised risk to the public or staff from outside nuclear medicine.

High Dosimetry Hijinks or How to Push your RPA One Step Closer to a Heart Attack

Dr Phil Orr, Radiological Imaging and Protection Service, Belfast Health and Social Care Trust

Background. A Trust's RPS and their RPA were contacted by the Approved Dosimetry Service to inform them of high dose exposure notifications for two radiographer's body dosemeters. The doses measured on the dosemeters were whole body doses of 661.85mSv and 174.17mSv! Once the RPA had picked themselves off the ground, in liaison with the RPS and Trust staff, they started an investigation of the doses to determine their veracity and potential causes. Due to the very high levels of dose HSENI were also informed.

Methods. The high doses were investigated in line with ACoP 558 including considering workloads and practice; results of monitoring (which included learning more about the structure of the dosemeters and their imaging capacity); incidents or other possible explanations for suspected overexposure; special radiation surveys carried out by the RPA trying to replicate similar doses and imaging patterns using primary and scatter exposures from different imaging modalities. Due to the potentially high doses, blood samples from the radiographers were also sent for analysis of chromosomal aberration.

Results. Imaging aspects of the dosemeters showed a clear pattern of nine dots (figure 1). This was replicated by a direct exposure by a DR unit (figure 2). Blood tests showed dicentric chromosomes in the normal range of 0-2 for both radiographers.

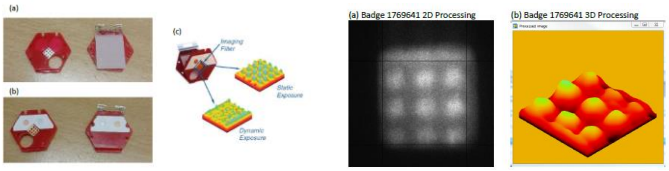

Figure 1: Structure of dosemeters and imaging results of radiographer dosemeter

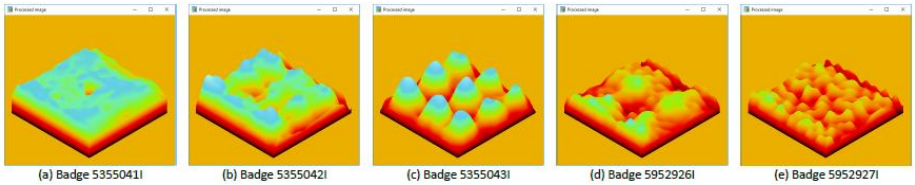

Figure 2: Images of dosemeters (a) directly irradiated on bed of CT scanner, (b) directly irradiated on gantry of CT scanner, (c) directly irradiated by 3D tube in DR Room, (d) irradiated by 1 month of scatter in CT room, (e) irradiated by 1 month of scatter in DR Room

Discussion. Chromosomal dosimetry results and poor practice of wearing dosemeters demonstrated that it was very unlikely the radiographers actually received the doses. The image properties of the dosemeter indicated direct irradiation by a stationary primary beam. Various theories were considered for the how the dosemeters received the doses. These included irradiation of the badge prior to arrival, occupational exposure, accidental exposure and deliberate irradiation. From the evidence, the best explanation was a deliberate irradiation by staff members "testing out" the dosemeters or trying to speed up remedial work on shielding. A number of radiation safety recommendations were made by the RPA. Results of the investigation were discussed HSENI who accepted the explanation and encouraged that the recommendations by the RPA were implemented. The ADS was contacted to amend results to a conservative estimate for the month (0.1mSv).

Conclusion. Due to the analysis of the imaging aspects of the dosemeters demonstrating direct exposure and the results of the blood tests of the affected staff members, it was determined that an actual exposure of staff members did not occur. Instead the evidence strongly indicated that the doses were most likely due to the deliberate irradiation of the badges using a 3D tube. Radiation practices needed to be reviewed within the Trust and a new line added to the Local Rules "Do not deliberately irradiated your personal dosemeter"!

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A New Model for Skin Dose Calculation for Alpha Emitters using VARSKIN+v1.1

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Introduction

I have previously shown that alpha emissions of some of the daughters of ^{223}Ra and ^{211}At can give very high skin dose values for 70 µm epidermal thickness using VARSKIN+v1.1 [1]. This derives from the daughters ^{215}Po and ^{211}Po (for ^{223}Ra and ^{211}At respectively), since their alpha energies are >7Mev, the threshold for 70 µm. However, that data used a fixed epidermal thickness value. In practice, the basal layer is highly convoluted, and 70 µm is only an average value. There is therefore a wide distribution of epidermal thicknesses at any skin site. [2,3]. This distribution can be used to obtain a truer weighted-sum dose estimate of alpha dose to the basal layer, which then includes significantly more alpha emissions.

Method

The distribution of epidermal thickness values is available for a range of tissue sites [2,3]. Varskin+ uses a 10µm basal cell thickness, so it is possible to calculate the skin dose at different epidermal thicknesses in 10 µm steps. These can then be combined with the epidermal depth distribution for a particular tissue site, and the weighted basal layer dose obtained.

Results

The table shows the instantaneous dose-rates (mSv/hr/kBq) for the fixed epidermal thickness, and for the weighted sum of epidermal thicknesses for the tissue sites of wrist, back-of-hand and face. These can be sites for contamination, e.g. during glove removal. They are shown for ^{223}Ra and ^{211}At.

		^{223}Ra Instantaneous mSv/hr/kBq		**^{211}At** Instantaneous mSv/hr/kBq	
Tissue Site	Mean Epidermal thickness [2]	Fixed thickness dose-rate	Weighted thickness dose-rate	Fixed thickness dose-rate	Weighted thickness dose-rate
wrist	81µm	3.3	9998	0.089	2440
Back-of-hand	85µm	3.2	3228	0.09	937
face	50µm	13860	14850	1996	3930

Discussion

The table shows that taking account of the epidermal thickness distribution can lead to significantly higher basal cell layer doses. This is particularly for tissue sites with mean thicknesses `>75µm , the maximum range for most alpha emissions. The instantaneous dose rates lead to 500mSv being obtained with ‘stuck’ (biological half-life of 3hrs assumed) activity on the skin of only 11Bq for ^{223}Ra and 47Bq for ^{211}At.

VARSKIN+ includes a QF of x20 for alphas. For deterministic effects, ICRP do not recommend applying the QF [2]. Also there is evidence that sparing of basal cells at deeper levels (e.g. around hair follicles) gives a much higher threshold for deterministic effects [4]. So it is likely that any typical accident will not lead to any deterministic effects.

Conclusion

Calculation of skin dosimetry with alpha emitters using VARSKIN+ software can significantly underestimate the radiation dose to the basal cells if a fixed dose-depth

value is used. Calculations based on the distribution of epidermal thicknesses for a particular tissue site may give a truer reflection of the basal cell dose.

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