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Radiation safety in interventional radiology and cardiology

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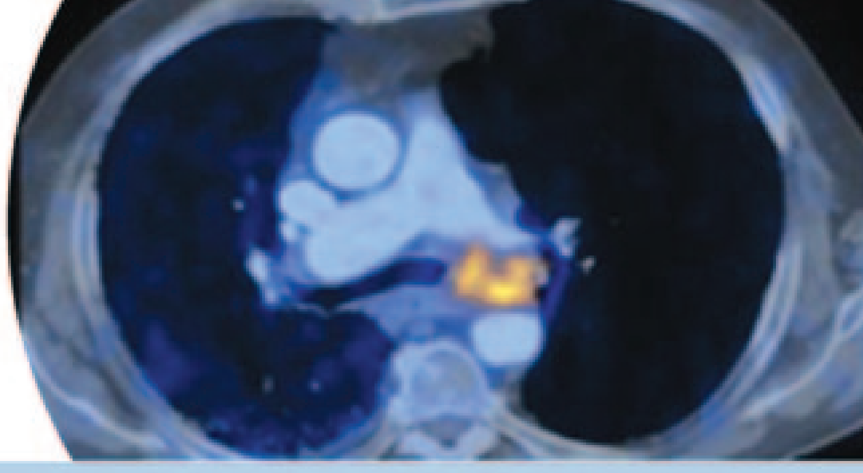

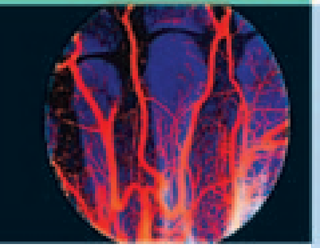

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Abstract

Interventional radiology and cardiology can be associated with a significant radiation hazard to staff. A risk assessment developed for each facility can be used to assess the radiation produced and to define the steps required to minimise the radiation exposure of staff. A hierarchy of control measures should be implemented, including the consideration of environmental and equipment features, working practices and personal protection. Monitoring, particularly relating to radiation exposure at different locations, is essential to ensure the adequacy of safety measures. Co-operation between radiation safety experts and clinical colleagues to define and maintain radiation safety conditions will enable appropriate protection of specialist staff.

Overview

Common features of interventional radiology and cardiology are the extensive use of fluoroscopy and fluorography – relatively lengthy dynamic procedures that can involve staff being close to the patient for long periods – and the use of open couch X-ray systems. This combination of factors presents a significant radiation hazard that demands careful measures to restrict the radiation exposure of staff. Patients can also be exposed to high radiation doses. The frequent need to image for long periods over the same region of skin can lead to deterministic effects such as erythema or dermal necrosis, the thresholds for which are 2 Gy and 20 Gy respectively.[1] Consequently, all acceptable measures that restrict the use of radiation are desirable and beneficial to patients and staff alike.

Understanding the radiation hazard

Figure 1. Scatter simulation in a cardiology laboratory. A stack of polymethyl methacrylate (similar in atomic number and density to tissue) is used to simulate the patient and radiation measurement is made with a large volume ionisation chamber.

The radiation hazard to staff stems predominantly from scattered radiation and needs to be determined either through theoretical prediction or experimental simulation (see Figure 1). Published data in the UK[2] gives a broad indication that a vascular or cardiac facility may generate a weekly dose-area product (DAP) reading in the range 1000–2000 Gy cm^2. The International Commission on Radiological Protection (ICRP) has published[1] suggested isodose curves for a typical interventional facility, indicating a hazard of 8 µSv per Gy cm^2 at 1.0 m. Local studies indicate that the position of the lead clinician will often be closer, e.g. around 70 cm from the scattering centre, indicating an approximate doubling of the suggested isodose level at 1.0 m. Putting this information together, the predicted dose at the 70 cm position over one year is in excess of 1200 mSv. A comparison of this value with existing dose limits[3–5] of 20 mSv (effective dose), 150 mSv (eye lens) and 500 mSv (extremities) demonstrates clearly how dose limits may be a small fraction of the potential hazardous radiation field and hence that safety is an essential issue to address.

Risk assessment

Realistically, safety conditions may only be properly understood through the development of a specific risk assessment for a facility.[6,7] The risk assessment should take account of:

- all relevant equipment factors (i.e. equipment settings, scatter dose rate)
- the hierarchy of safety control (see below)
- staff activity (where staff stand, how work is shared), and
- workload

to predict staff exposure.

In doing this, it is important to incorporate accurate information whenever possible, linked with clearly defined and reasonable assumptions where necessary. Remember that the results of personal monitoring indicate what doses staff actually receive; the risk assessment helps understanding of how the doses can arise and how they may be reduced.

Creating safe conditions

To attain a high standard of radiation safety, it is essential to follow an appropriate hierarchy of control measures.[6,7]

1. Implement safety features of the radiography equipment and environment

For the equipment, important features include:

- options for acquisition doses and fluoroscopy dose rates
- spectral control options
- pulsed fluoroscopy
- the use or omission of an anti-scatter grid
- electronic collimation, and
- real-time indications of patient dose.

Prominence and significance should be given to such options during the procurement of equipment and when devising protocols for clinical procedures.

With regard to the working environment, features such as:

- couch-mounted screens (lower extremities)
- ceiling-suspended protection screens (eye lens, thyroid, upper body), and
- portable control pedestals (to control distance from the patient)

can all help to restrict doses to staff.

2. Develop a written system of work

Consideration must be given to how staff work in the environment, leading to a written system of work for the facility. The system of work should, for example, ban unnecessary presence in the hazardous environment and encourage staff to retire as far as possible from the patient whenever possible. A member of the radiological team should have a special duty to monitor and enforce the system of work: in the UK, for example, a radiation protection supervisor is strictly required.[6]

3. Administer personal protection

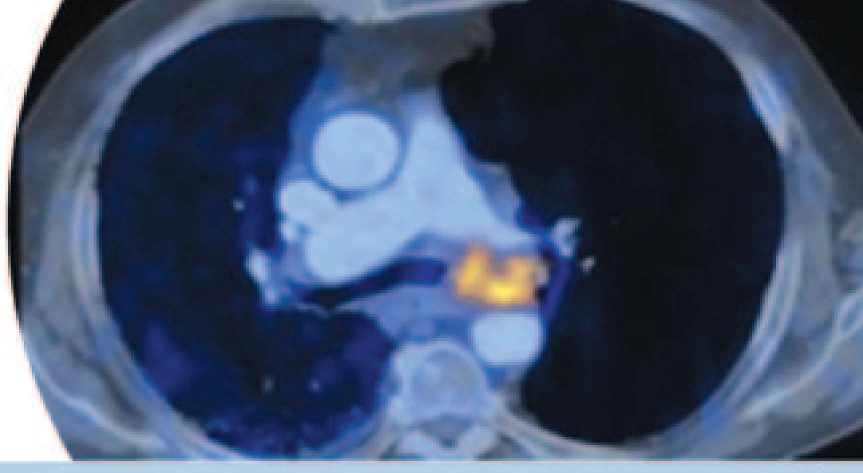
Options of personal protection should include:

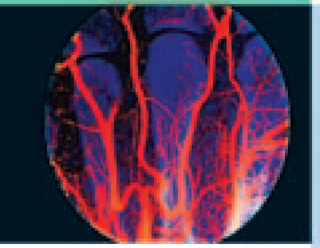
- whole body protection (aprons or two-piece garments)
- thyroid shields, and
- protective goggles or spectacles.

Attention should be paid to the degree of protection that each option may provide and its practicality. For example, the transmission of X-rays through lead aprons typically ranges from 1.5–7% for 0.35 mm lead equivalence to 0.5–3.5% for 0.5 mm of lead equivalence, over the expected spectrum of X-rays. For protection, a lead equivalence of 0.5 mm is preferred for demanding work, though aprons can prove uncomfortable if worn for long periods. Two-piece garments can improve comfort and provide the added benefit of a double layer of wrapped protection across the chest.

Radiation safety in interventional radiology and cardiology *continued*

Mark Hanson





The protective effect of spectacles rests not only on the lead equivalence (which is typically 0.5 mm) but also on the area of the lens: with small lenses, there is an increased risk of eye-lens exposure to a backscatter of radiation arising from the surrounding tissues.

Monitoring

Monitoring of personnel is required to ensure that the safety measures in place are effective. In this context, direct or indirect monitoring of dose to the eye lens, thyroid and extremities may prove to be essential, in addition to whole body monitoring. It is important to note that dosemeters used to cover work at more than one facility can provide assurance but cannot reveal where contributory exposure has taken place, making linking to risk assessment difficult. There is an immediate need to correlate dose monitoring results with work at different locations. Any failure to sum the radiation doses for individuals, or instances where the monitoring is inadequate or absent, can lead to a potentially serious risk to the individual and a breach of the law.

Worked example

The information shown in Table 1 relates to a cardiology laboratory that receives safety support from the author's team. This is an informative example because the dose monitoring information is particularly reliable, excellent safety standards are maintained in the laboratory, and the outcomes can be correlated with a detailed risk assessment. The information (see Table 1) demonstrates how actual results should relate to risk assessment, how dose reduction measures are important, and how the potential for relatively high dose is significant. The dose values may be compared with the annual dose limit of 20 mSv and the classification limit of 6 mSv. The key outcome is how the low maximum entrance dose of 0.26 mSv could rise as high as 4.2 mSv if poor safety standards were maintained, bearing in mind that no account is given here of any radiation exposure that may be received by the same staff working at other facilities.

Conclusions

There is an unquestionable need for radiation safety experts and clinical colleagues to work in close co-operation to define and maintain appropriate radiation safety conditions in interventional and cardiological facilities. High risk patients and specialist staff are both precious: we need to look after them with equal care

Key Learning

- Interventional radiology and cardiology can be associated with a significant radiation hazard, predominantly due to scattered radiation
- Risk assessments should be used to understand how radiation doses may arise and how they can be reduced
- Use appropriate control measures, e.g. optimising environmental conditions, equipment features, working practices and personal protection, as well as monitoring of personnel to minimise risks

Table 1. Example of assessing radiation exposure in a cardiology laboratory

Source	Description	Dose (mSv)
Risk assessment (prediction)	**Maximum predicted** annual dose in air (i.e. external to any lead apron) to the normal cardiologist's position. *This value is derived from careful simulation and measurement of scattered radiation linked to realistic workload assumptions*	104
	Minimum predicted annual dose (corresponding to above) assuming full use of dose reduction measures (e.g. low dose imaging, no grid)	11.1
Monitored doses	**Actual** annual dose derived from summing the shoulder monitors (i.e. dosemeters worn external to lead apron) of all the cardiologists using the facility, i.e. the measure value that corresponds exactly with the risk assessment prediction	16.5
	The maximum annual **individual** dose recorded external to the lead apron from the group of cardiologists (n.b. 6 in this case)	7.5
	The maximum individual annual **entrance** dose (i.e. below the lead apron) corresponding to the 7.5 mSv reading above, assuming 3.5% transmission through the apron	0.26
Potential maximum entrance dose	This is how the 0.26 mSv figure would rise if (a) the clinical work was not shared (b) a 0.35 mm lead apron (not 0.5 mm) was used (c) no work was performed using low dose imaging and (d) the cardiologist stood 15 cm closer during procedures than assumed in the risk assessment	4.2

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