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REVIEW

A Review of Radiation Protection Solutions for the Staff in the Cardiac Catheterisation Laboratory

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Adverse health effects of radiation exposure to staff in cardiac catheterisation laboratories have been well documented in the literature. Examples include increased risk of cataracts as well as possible malignancies. These risks can be partly mitigated by reducing scatter radiation exposure to staff during diagnostic and interventional cardiac procedures. There are currently commercially available radiation protection tools, including radioprotective caps, gloves, eyewear, thyroid collars, aprons, mounted shields, table skirts and patient drapes to protect staff from excessive radiation exposure. Furthermore, real-time dose feedback could lead to procedural changes that reduce operator dose. The objective of this review is to examine the efficacy of these tools and provide practical recommendations to reduce occupational radiation exposure with the aim of minimising long-term adverse health outcomes.

Keywords Radiation protection • Interventional cardiology • Cardiac catheterisation laboratory • Radiation safety

Introduction

The two major sources of radiation exposure to staff in the cardiac catheterisation laboratory are scattered x-ray photons from the patient's body and x-ray tube leakage. Ionising radiation poses a health risk to staff members in the catheterisation lab in the form of stochastic or deterministic effects. Stochastic effects describe the probability of cancer or DNA damage due to ionising radiation. This effect is believed to have no threshold radiation dose and the chance of the effect increases in a linear fashion with increasing dose. On the other hand, deterministic effects, such as skin injury due to radiation exposure, have a threshold dose below which the probability of causing harm is zero. Due to the comparatively large threshold dose required, deterministic effects are seldom discussed in the context of staff radiation dosimetry in the cardiac catheterisation laboratory.

Table 1 summarises the quantities and measures of radiation dosimetry that are commonly used. The lens of the eye is a region of particular interest with a number of studies showing an increased incidence of cataracts amongst catheterisation laboratory staff members [1–5]. The occupational effective dose limit to radiation workers is 20 mSv per year averaged over five years and the dose limit for the eye has recently been reduced from 150 mSv to 20 mSv a year to further protect against the rising number of radiation induced cataracts [6]. The occupational effective dose limit is believed to reduce any radiation induced injury to staff members, since doses below 100 mSv accumulated over a year do not appear to have any statistically significant association with carcinogenesis [7]. Recent evidence suggests that even protracted low dose radiation exposure could be associated with leukaemia, carotid artery atherosclerosis and early vascular ageing [8,9]. Therefore, efforts need to be made

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Table 1 Description of radiation quantities commonly encountered in the catheterisation laboratory

Quantity	Description	SI Unit
Reference Air Kerma	Energy released per unit mass of air at the interventional reference point, which is located at 15 cm from the isocenter towards the X-ray tube.	Gray (Gy)
Organ Absorbed Dose	Integral or average absorbed dose over a whole organ mass	Gray (Gy)
Dose Area Product	The integral of air kerma multiplied by the irradiated field area	$Gy.cm^2$
Effective Dose	A tissue-weighted sum of the absorbed dose in irradiated organs and a representation of the patient stochastic risk	Sievert (Sv)
Peak Skin Dose	The accumulated absorbed dose to the highest irradiated area of the skin	Gray (Gy)

to keep the dose as low as reasonably achievable (ALARA principle), regardless of occupational dose limits.

Radiation attenuating material, such as lead, has long been used as a component of protective equipment to decrease the amount of radiation received by staff. This includes aprons, glasses and gloves as well as movable shields, and with appropriate use will lower radiation exposure. Implementing radiation dose feedback may also have a role in reducing exposure. This paper reviews the available tools to lower dose to the operator during diagnostic and interventional cardiac procedures.

Radiation Shielding

Caps

Reports regarding operator brain tumours associated with fluoroscopically-guided procedures have raised concerns regarding appropriate shielding to the head [10–12]. Although the risk of malignancy is thought to be low, lead caps introduced in the past have been shown to be effective in lowering the exposure to the head. Furthermore, the use of lead caps has been shown to reduce the dose to the head by up to 30 times more than ceiling-mounted lead shields [13,14]. However, the average weight of these caps is 1.14 kg, which may be uncomfortable to wear and could present an occupational health and safety hazard. Back problems are prevalent amongst interventional cardiologists due to the necessity of wearing a lead apron (up to 7 kg) and adding extra weight to what is already standard is not an optimal solution [15,16]. A recent study tested the radioprotection efficacy of new lightweight lead equivalent caps containing a barium sulphate-bismuth oxide composite [17]. These caps, when worn in addition to standard use of other radioprotective tools, provided up to 90% dose reduction to the head, weigh an average of 125 g and are comfortable to wear (Figure 1). A study using an even lighter cap containing the same materials and weighing approximately 50 g was found to reduce the radiation dose to the head by 80% [18]. Although they are reusable, the lifespan of a cap is unknown and will depend on its care.

While radioprotective caps do provide substantial dose reduction, whether they prevent radiation-induced illness is unknown. The cost of a lightweight radioprotective cap at the time of writing is about AUD$10, but there are insufficient data to comment on cost-effectiveness. In cardiac procedures that are likely to give rise to high operator dose, consideration should be given to wearing them. There is evidence to suggest that dose to the head is lower in operators taller than 180 cm in height, with a decrease in dose to the head of 1% per cm of operator height[13]. Hence, these caps may be of greater benefit in operators of shorter height.

Gloves

The hand receives a significant amount of radiation (45-1500 μSv per procedure) during procedures since it is unshielded and close to the radiation source [19]. However, this level of exposure is unlikely to cause any adverse health impact. Leaded gloves are available but are large and cannot be used when dexterity is required. The use of leaded (or lead-free) radiation attenuating latex gloves introduced in some centres helps address these issues. These gloves, according to manufacturer claims, can shield the hand by up to 58% [20]. However, if the hand with an attenuating glove is placed in the direct radiation beam then the dose to both the patient and operator will increase because the automatic brightness control system in current x-ray systems will boost the radiation output (Figure 2). The best method to protect the hands would be to keep them away from the primary beam. In cases where the hands must be close to the patient such as during a fluoroscopically-guided vascular puncture, protective gloves may be an option. However, procedural modifications such as using a long needle or syringe to extend the working length of a needle may be preferable. When gloves are used, single-use, non-lead radioprotective gloves are recommended since they can be safely disposed of after a procedure unlike a leaded glove.

Eyewear

Radiation induced cataracts in operators and nursing staff are a well-documented risk. Results from various studies show that radiation associated lens changes were recorded in up to 52% of subjects who have worked an average of nine years as compared to lens changes in up to 12% in a non-exposed group [1,3–5]. A number of studies show that using leaded glasses lowered the dose to the lens by up to 98% [21–23]. A study