

Background

The protection of medical personnel in interventional radiology is an important issue of radiological protection. The irradiation of the worker is largely non-uniform, and a large part of his body is shielded by a lead apron. The estimation of effective dose (E) under these conditions is difficult and several approaches are used to estimate effective dose involving such a protective apron. This study presents a summary from an extensive series of simulations to determine scatter-dose distribution around the patient and staff effective dose from personal dosimeter readings. The influence of different parameters (like beam energy and size, patient size, irradiated region, worker position and orientation) on the staff doses has been determined. Published algorithms that combine readings of an unshielded and a shielded dosimeter to estimate effective dose have been applied and a new algorithm, that gives more accurate dose estimates for a wide range of situations was proposed.

Objectives

A computational approach was used to determine the dose distribution in the worker's body. The radiation transport and energy deposition was simulated using the MCNP4B code. The human bodies of the patient and radiologist were generated with the Body Builder anthropomorphic model-generating tool. The radiologist is protected with a lead apron (0.5 mm lead equivalent in the front and 0.25 mm lead equivalent in the back and sides) and a thyroid collar (0.35 mm lead equivalent). The lower-arms of the worker were folded to simulate the arms position during clinical examinations (figure 1). This realistic situation of the folded arms affects the effective dose to the worker. Depending on the worker position and orientation (and of course the beam energy), the difference can go up to 25%.

A total of 12 $H_p(10)$ dosimeters were positioned above and under the lead apron at the neck, chest and waist levels. Extra dosimeters for the skin dose were positioned at the forehead, the forearms and the front surface of the upper legs.

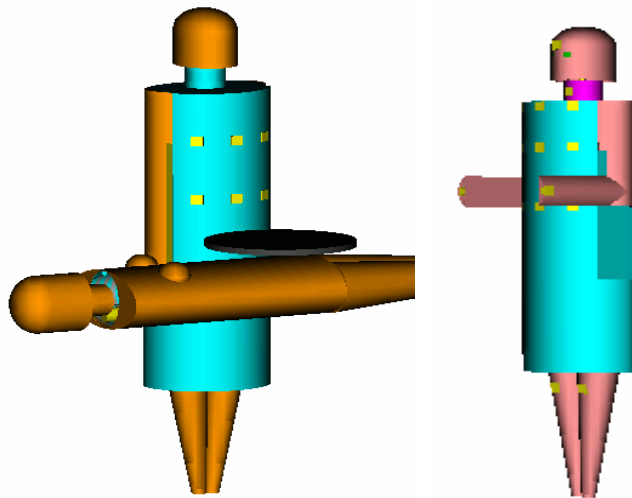
Principal results

Simulations were done for different X-ray tube orientations (lateral, posterior-anterior), for different irradiated region of the patient (pelvis, abdomen, chest and head) and for X-ray spectra going from 66 to 96 kVp. The scatter doses were calculated in a three dimensional space next to the patient side. In figure 2, an example is given in the horizontal plane for a pelvis examination (posterior-anterior, 76 kV). The lowest normalized air kerma values correspond to the irradiation of the thorax region, the highest to the irradiation of the head region. Once the scatter field around the patient was determined, the organ doses and effective dose to the worker, relative to the dose-area-product, were calculated for 17 different worker positions. In general, the lowest staff effective dose was observed for pelvis examinations, the highest for head examinations. The orientation of the X-ray tube has a large influence. The highest worker effective dose was observed for lateral irradiations of the patient's abdomen. For the head region, the over-couch projection presented the higher effective dose. The calculations also demonstrated that the effective dose to the worker is proportional to the beam size on the patient and also an increase in patient size will lead to an increase in worker effective dose.

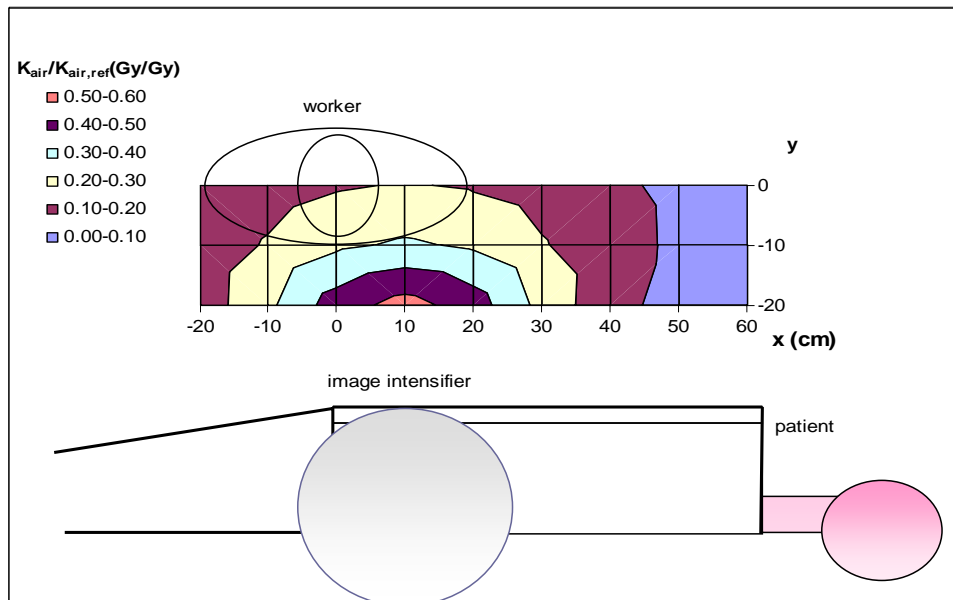
Several authors have derived algorithms to allow the estimation of the worker effective dose from personal badge readings. For all the simulations (133 in total: 66-96 kVp, 5 worker positions, 8 different projections) those algorithms have been evaluated and compared to the effective dose. It was clear that large underestimations (from 0.8 to 0.01) can occur with the present algorithms. A new algorithm was derived using all the simulations done in this study, using multiple linear regression analysis. The following algorithm was obtained for under couch & lateral projections:

$$0.125 H_p(10)_{\text{chest,on,mid front}} + 2.4 H_p(10)_{\text{waist,under,left front}}$$

Over couch projections have not been included in this formula, because these are found only in old equipment.



Patient and staff anthropomorphic phantoms.



$K_{air}/K_{air,ref}$ for a pelvis examination, posterior-anterior projection at 76 kV in a horizontal plane

Future developments

Experimental validation of all these scatter spectra calculations around the patient should also be of interest to the study. In practice, doses to the workers are measured by personal dosimeters worn above or/and under the lead apron. The use of active personal dosimeters in interventional radiology are being evaluated by Working Group 9 (Radiation protection dosimetry of medical staff) of the CONRAD project. We take part of the activities of this working group, which is a Coordination Action supported by the European Commission.

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Main reference

J. Pages, *Calculation of staff doses in complex radiological examinations*, thesis submitted for the degree of Master of Science in Nuclear Engineering, BNEN, september 2005