Scattered radiation during fixation of hip fractures

IS DISTANCE ALONE ENOUGH PROTECTION?
From Bradford Royal Infirmary, England

We measured the scattered radiation received by theatre staff, using high-sensitivity electronic personal dosimeters, during fixation of extracapsular fractures of the neck of the femur by dynamic hip screw. The dose received was correlated with that received by the patient, and the distance from the source of radiation. A scintillation detector and a water-filled model were used to define a map of the dose rate of scattered radiation in a standard operating theatre during surgery. Beyond two metres from the source of radiation, the scattered dose received was consistently low, while within the operating distance that received by staff was significant for both lateral and posteroanterior (PA) projections.

The routine use of lead aprons outside the 2 m zone may be unnecessary. Within that zone it is recommended that lead aprons be worn and that thyroid shields are available for the surgeon and nursing assistants.

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The development of new radiological techniques and portable image intensifiers has made fluoroscopic screening a routine practice in orthopaedic operating theatres. Theatre staff are thus exposed to ionising radiation on a regular basis, with potential harmful effects.1-4 The dose of radiation received by staff depends on the dose given to the patient, its duration, the distance from the radiation source and the degree of shielding of the staff.5 Previous studies have analysed the exposure for orthopaedic surgeons in the operating theatre,6-10 the relationship between the level of experience of both the surgeon and the radiographer, and the dose of radiation administered during specific procedures.11

Our study analyses the scattered radiation in orthopaedic trauma theatres during fixation of extracapsular fractures of the neck of the femur. Empirically, we have mapped dose rates of scattered radiation, taking into account the arrangement of the operating table and equipment in the theatre.

Materials and Methods

Scattered radiation was measured during the fixation of extracapsular fractures of the neck of the femur by a dynamic hip screw (DHS) in ten patients admitted to the Orthopaedic Department of Bradford Royal Infirmary. All operations took place in the same theatre, with the same operating equipment and with trained theatre staff using the same image intensifier (Siemens-Siremobil 2000; Siemens Medical Solutions Group, Eschborn, Germany) for both posteroanterior (PA) and lateral projections. The procedures were undertaken by several senior radiographers and several surgeons (consultants and specialist registrars).

Siemens EPD-2 electronic personal dosimeters (EPDs) were given to the surgeon, assistant, scrub nurse, anaesthetist and radiographer. Each dosimeter was clipped to the outside of the lead apron at the beginning of the procedure and readings were recorded at the end. The EPDs had a sensitivity threshold of 1 μSv, up to 100 times more sensitive than the thermoluminescent dosimeters used in previous studies,5,6,9,12 and they have an appropriate energy response for diagnostic radiology. The dose quantities measured were the penetrating individual dose equivalent (Hp, 10), and the superficial individual dose equivalent (Hs, 0.07), representing the dose to tissue at a depth of 10 and 0.07 mm, respectively, and these are expressed in units of μSv.13 The radiographer recorded exposure time and the range of exposure factors used during the procedure from the control panel of the image intensifier, for each case. A calibrated dose area product (DAP) meter recorded the exposure of the patients to radiation in units of cGy.cm².
Empirical measurements. The same theatre was prepared according to the routine procedures for DHS fixation including an operating table, surgical instrument trolleys and anaesthetic trolley. The theatre floor was marked at 50 cm intervals from the centre of the operating table in all directions. To simulate the absorption and scatter characteristics of the human body, a water-filled model, mimicking the pelvis (20 cm × 20 cm × 15 cm) and abducted limb (a cylindrical phantom length 30 cm and radius 5 cm), was placed on the operating table with the x-ray beam projected as in the standard procedure.

A scintillation detector (Automess Szintomat) was used to measure the dose rates of scattered radiation (sensitivity 0.01 μSv/hr) at waist level (1 m from the floor) on each 50 cm mark and at neck level (1.6 m from the floor). In addition, EPDs were used to measure the dose of radiation at the level of the waist and neck. The dose rate measured at the location of the EPDs was multiplied by the fluoroscopic screening time for comparison of this measurement with the cumulative dose measured by the EPDs.

Results

The output of radiation was calculated from the data recorded by the radiographer at the end of each procedure. The mean patient-recorded DAP was 115.2 cGy.cm² (56 to

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\[\text{Fig. 1}\]

Distance from the radiation source and the scattered radiation received by theatre staff per procedure.

\[\text{Fig. 2}\]

Map of dose rate of scattered radiation at intervals of 0.2 μSv (lateral projection).
The mean exposure time was 25.8 seconds (12 to 42), which is similar to that in previous studies.\textsuperscript{11}

The data obtained during the procedures are shown in Figure 1. The circles represent the distance in metres from the source of radiation on the Y axis to the right; the columns represent the mean penetrating (Hp) and mean superficial (Hs) doses in μSv received by the different members of the theatre staff on the Y axis to the left. The maximum scattered dose measured was in the surgeon’s EPD with 37 μSv in a single surgical procedure, while the anaesthetist’s EPD recorded only 1 μSv as a maximum dose on two occasions. The smallest surgeon’s dose recorded was 7 μSv while the anaesthetist and radiographer showed zero measurements in their EPDs on eight and seven occasions, respectively. These results confirm previous published studies using less sensitive dosimeters.\textsuperscript{5,6,14-16}

For the empirical measurements, the image intensifier was set up at 67 kV on the PA projection and 85 kV on the lateral projection to reproduce the scatter characteristics encountered during surgery. The dose rate, measured at multiple points, was used to plot a map of the scattered radiation across the theatre as shown in Figure 2. The dose rate was recorded at the level of the waist using the scintillation detector.

Figure 3 shows the dose recorded by EPDs placed where the surgeon would normally stand, measured at the levels of the waist and neck. The cumulative dose for each projection was divided by the corresponding DAP reading to give an objective comparison of the dose per unit DAP between the PA and lateral projections. The measurements show that the surgeon gets a much higher dose from lateral exposures. They also indicate that there is a significant difference between the ratios (neck relative to waist) of the PA and lateral projections; and they show that the dose decreases with distance from the irradiated skin surface.

Discussion

The use of lead aprons by all theatre staff working in a controlled area, as defined by the local rules under the Ionising Radiations Regulations 1999\textsuperscript{17} (IRR99), is accepted practice in UK hospitals. The findings of our study question the need for defining the whole theatre as a controlled area. Care should be taken to establish the extent of the controlled area and to provide appropriate protection measures for those who are at real risk from exposure to ionising radiation.

As expected, the amount of scattered radiation measured was inversely proportional to the distance from the source of radiation, although not in a strictly inverse square relationship because the patient acts as an extended source of scattered radiation. These findings provide sufficient evidence to indicate revision of the local radiation protection policy on defining the controlled area to within the confines of the theatre. Since, for this procedure, scattered radiation was insignificant beyond two metres from the source of radiation, the use of lead aprons outside the operating area of the theatre may be unnecessary. Given that those outside the 2 m zone are at little or no risk from exposure to radiation, the ergonomic disadvantages of wearing lead aprons may outweigh the benefits offered by their protection. Protection for the neck should be made available within the 0.5m distance from the irradiated area.

According to the IRR99 the annual dose limit for the whole body is 20 mSv. If, however, there is a risk of the dose approaching 6 mSv, the individual should be designated as ‘classified’. This may occur in a busy trauma
centre for those who fail to wear lead protection. Routine monitoring should be carried out for this group.

The need to change into a lead apron before entering the operating theatre may cause delay, for example when bringing in extra equipment, thereby prolonging anaesthetic time. Statutory regulations require the employer to keep the dose of radiation to persons ‘as low as reasonably practicable’ (ALARP). The disadvantages of wearing lead aprons must be weighed against the ALARP principle.

We have shown that outside the 2 m zone staff receive less than 1 μSv per procedure. Therefore the use of lead aprons may be impracticable when other risk factors for staff and patients are considered. Within this ‘controlled area’ a lead thyroid shield should be made available for the surgeon, assistant and scrubbed nurse, in addition to a lead apron.

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References