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Ionising radiation: are orthopaedic surgeons at risk?

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Modern orthopaedic trauma practice involves increased exposure of the surgeon to ionising radiation. However, there have been no studies to investigate whether the doses received are within limits for non-classified workers. In this study, whole body, eye and extremity, namely hand, doses were measured in six orthopaedic surgeons during trauma cases requiring the use of X-rays in theatre. None of the subjects approached the recommended maximum dose levels for either the whole body, eyes or hands. This finding is reassuring. In orthopaedics, the limiting dose is that to the hands. This differs from previously studied groups, such as radiologists and cardiologists, in whom the limiting factor is the dose to the lens of the eye. Although current precautions appear to be adequate, safe practice in the future will depend on continuing vigilance and repetition of studies similar to this one as techniques and workloads change.

There is abundant literature on the risks of working with ionising radiation in certain groups within the medical profession, such as radiologists *(1)* and cardiologists who perform radiological studies *(2)*. However, with trends towards internal fixation in modern orthopaedic trauma practice, the orthopaedic surgeon finds himself spending more time in theatre next to an image intensifier or other radiation source. We could not find a single study in the literature which has looked at the radiation risk in this group.

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The Ionising Radiation Regulations 1988 *(3)*, which are based on a European Community directive, have made it compulsory, from June 1990, for all staff working with X-rays to receive formal tuition, at special ionising radiation courses, in the hazards of ionising radiation and the safe use of X-ray equipment. This tuition is aimed primarily at the protection of the patient. Despite growing awareness of potential dangers to orthopaedic staff, no data exist on the radiation doses received by orthopaedic surgeons at work. The aim of this study was to determine whether the radiation exposure of orthopaedic surgeons in a busy trauma unit was within the dose limits recommended in the Ionising Radiations Regulations 1985 *(4)*.

Materials and methods

Measurements were undertaken of the exposure of six operators (three senior registrars and three registrars) during all procedures performed for trauma which required the use of plain X-rays or the image intensifier in theatre.

Each surgeon wore two film badges, one underneath the lead apron to ascertain the whole body dose, and the other on the shoulder closest to the X-ray source in order to estimate the dose to the lens of the eye and the thyroid.

Film badges consist of a piece of photographic film under various filters in a plastic holder. The film is blackened by ionising radiation to a degree which depends on the dose received and the energy of the radiation. If the energy of the radiation in question is taken into account, the density of the film will indicate the dose received. The filters absorb different fractions of radiation depending on the material and thickness of the particular filter. By determining the ratios of densities of the film beneath different filters, an energy factor for the radiation encountered can be calculated. The density of a given staff film is obtained using a densitometer. This value is corrected for the energy of the incident radiation by application of the energy factor, calculated as above. The dose received may then be read from a calibration graph of film density versus exposure.

A thermoluminescent dosimetry (TLD) device was also worn strapped to the dorsum of each hand under double gloves, to measure extremity dosage.

TLD devices are small Teflon® discs with a diameter of 5 mm. The small size makes them ideal for monitoring extremity doses. Their operation depends on the thermoluminescent properties of materials such as lithium fluoride which they contain. When irradiated, the energy of irradiation raises electrons from the valence bands to optical bands where they are caught in electron traps, in which they remain as long as the temperature does not exceed 300°C. When heated above this level, the electrons have enough energy to overcome the traps and return to the valence bands. In doing so, they surrender the energy acquired on irradiation in order to be more tightly bound to the nucleus. This energy appears in the form of light, the intensity of which is proportional to the energy initially absorbed on irradiation. The light intensity can be measured and, when calibrated, is equivalent to the radiation dose received.

The accuracy of both the film badges and the TLD technique is ±20% in the laboratory involved in the study. These levels of precision are adequate for the purposes of determining whether an encountered exposure is within safe limits.

During the study, standard 0.3 mm lead equivalent protective aprons were worn for all cases.

A Siemens Siremobile® series 2 image intensifier was used in all cases requiring X-ray images. This model has a memory which continues to display the image on the screen after the beam has been turned off.

At the end of each month, the film badges and TLD devices were taken for reading to the Department of Medical Physics, which is recognised by the Health and Safety Executive as a monitoring laboratory.

We compared the doses received by the orthopaedic surgeons under investigation with *pro rata* monthly doses calculated from the recommended annual dose limits for non-classified radiation workers as stipulated in the Ionising Radiations Regulations 1985 *(4)*.

Results

There were 63 trauma admissions during the first month of the study, of which 57 required surgery. Of these, 31 operations involved the use of the image intensifier or plain X-rays (Table I). Each surgeon participated in an average of eight cases (range 3–15).

Table I.

Type of operation	*Number performed*
Hip screw	10
Intramedullary nailing	3
Internal fixation of fractures	8
Application of external fixator	2
Manipulations	8

Table II.

		Radiation dose (mSv)			
Surgeon	*Exposure (s)*	*Film badge under apron*	*Film badge on shoulder*	*TLD right*	*TLD left*
Senior registrar 1	108	<0.2	<0.2	0.15	0.19
Senior registrar 2	378	<0.2	<0.2	0.19	0.25
Senior registrar 3	165	<0.2	<0.2	3.80	0.54
Registrar 1	1196	<0.2	<0.2	2.83	2.45
Registrar 2	755	<0.2	<0.2	0.64	0.53
Registrar 3	300	<0.2	<0.2	3.95	3.35

The mean tube voltage setting on the image intensifier was 65 kV (range 40–89 kV), for a mean time of 53 s (range 3–246 s) per procedure. The intramedullary nailings, however, required much longer screening times with an average of 144 s, compared with an average of 43 s for the other procedures.

The doses received during the first month of the study (31 days) and the total number of seconds of exposure are tabulated for each surgeon in Table II.

The results of the first month of the study were so conclusive that the Department of Medical Physics at University College Hospital, which is responsible for monitoring radiation exposure throughout the district, advised us that there was no need to continue the study for a further 2 months.

Discussion

Staff working in any industry who are exposed to radiation that exceeds 30% of the limits laid down in the Ionising Radiations Regulations 1985 *(4)* are termed 'classified' radiation workers. As such, they are subject to certain statutory requirements from which non-classified workers are exempt, for example compulsory continuous monitoring and an annual medical.

On average, there are 61 trauma admissions per month to our orthopaedic unit, of which 58 require an orthopaedic surgical procedure (departmental audit data). The study month thus represents a typical monthly workload. Two of the orthopaedic registrars monitored had minimal previous operative experience in orthopaedic surgery at the beginning of the study, so that they were more likely to use longer screening times than more experienced colleagues performing the same procedures. Our results are, therefore, likely to represent worse than average levels of exposure.

The recommended annual whole body dose limit for non-classified workers is 15 mSv *(4)*, giving a *pro rata* monthly dose of 1.25 mSv. All the orthopaedic staff studied received doses well below this level, with even the highest whole body dose recording only one-tenth of the acceptable monthly value.

In many situations, however, the effective dose is only a fraction of the dose to a single organ or tissue. In these cases, the individual organs become the critical factors in the assessment of radiation hazards. For this reason, we measured the doses to the lens of the eye and to the hands, in addition to the whole body dose.

The lens of the eye is particularly sensitive to radiation, with long-term exposure resulting in cataracts, so that the acceptable maximum annual dose for non-classified workers at 45 mSv *(4)* is lower than for other organs. This figure corresponds to an acceptable monthly dose of 3.75 mSv. In radiological *(1)* and cardiological *(2)* practice, the lens of the eye is the limiting factor in determining maximum acceptable exposure levels. In this study, the shoulder badge readings, which represent the eye dose, were all lower than the recommended limit by a factor of twenty or more. In the future, workload is unlikely to increase to the extent that the lens dose limit is exceeded.

The extremity dose is of particular relevance in orthopaedic practice because of the proximity of the hands to the beam during screening in many procedures. The recommended annual dose limit for the extremities of non-classified radiation workers is 150 mSv *(4)*, giving a *pro rata* monthly dose of 12.5 mSv. None of the extremity doses, as measured by the TLDs, exceeded this value, but the safety margin was much smaller than for the eye doses. A fourfold increase in workload would increase the dose received by the operators with the two highest extremity readings above the limit for non-classified workers. It seems that in orthopaedics the limiting factor in radiation exposure is the extremity dose, as opposed to the eye or whole body doses. This differs from the two other hospital medical groups at risk, namely the radiologists and the cardiologists. Retiring during screening can significantly reduce the dose received *(2)*, and the precaution of withdrawing the hands from the beam should be practised when possible. Sometimes, when manipulating unstable fractures, it is impossible to remove the hands without losing the reduction of the fracture. In these situations, lead gloves may be useful. Although bulky, they confer adequate protection.

Since completion of the study, the International Commission on Radiological Protection (ICRP) has revised its guidelines on dose limits *(5)*. While the eye and extremity limits are unchanged, a reduction in the acceptable annual whole body dose has been recommended. Although not yet incorporated into British legislation, it is anticipated that these new proposals will soon be adopted in this country. The ICRP suggests a reduction in the annual whole body dose limit from 50 mSv to 20 mSv. If this dose limit reduction were to be applied to the UK, the annual whole body limit for classified workers would be reduced to 20 mSv per annum and that for non-classified workers to 30% of this figure, i.e. 6 mSv. The whole body doses encountered in this study are well below the new recommended limits and our conclusions are, therefore, unaltered by the recent ICRP proposals.

There are at present, following rigorous and, in some cases, continuous staff monitoring, no classified radiation workers employed in the health district in which the study took place.

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