RADIATION DOSAGE FROM USE OF THE IMAGE INTENSIFIER IN ORTHOPAEDIC SURGERY

N N Lo, P S Goh, K S Khong

ABSTRACT

The image intensifier is now commonly used in orthopaedic surgery for intraoperative assessment of fracture reduction and implant placement, especially with the increasing trend toward use of closed nailing devices. We conducted a study using lithium fluoride chips to measure the radiation dosage to the surgeon and the operating theatre personnel.

Over a 6-month period we measured the cumulative radiation dosage over the eyes (0.83mSv), thyroid (with shield 0.51mSv, without 0.79mSv), waist (with apron 0.48mSv, without 0.86mSv), hands (right 0.7mSv, left 0.14mSv) and feet (0.62 mSv). These values were well within the ICRP safety guidelines. The use of protective lead shielding was effective in reducing radiation dosage to operators. A survey of the operating theatre area using a radiation counter showed that radiation scatter to OT personnel was low. This study hopes to allay the fears that use of the image intensifier is hazardous to OT personnel.

Keywords: *radiation, orthopaedic surgery, fractures, fluoroscopy, safety.*

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INTRODUCTION

The number of orthopaedic procedures requiring the use of fluoroscopic guidance has increased over the recent years. It is now accepted that closed operative procedures are the treatment of choice in many types of complex fractures because of their lower infection and non-union rates, smaller incisional wounds and relatively low morbidity at implant removal. The use of such procedures has increased in popularity. As these procedures require considerable amount of fluoroscopic guidance, the staff in our operating theatres have voiced concern over the danger of excessive exposure to radiation. We conducted this study to determine the amount of radiation dosage from routine use of the image intensifier in the orthopaedic operating theatre.

MATERIALS AND METHODS

The radiation dosage to the surgeon was measured using thin layer lithium fluoride thermoluminescence dosimetry chips (TLD, Harshaw Chemical, Ohio). The chips were taped to specific parts of the body. The areas selected were the forehead (for measuring radiation to eyes), the dorsum of both wrists, in front and behind the thyroid shield at the neck, in front and behind the lead apron at the level of the waist, and over the dorsum of both rubber theatre boots.

The radiation dosage from consecutive elective operations requiring the use of an image intensifier was measured over a 6-month period. A 4-year-old mobile C-arm (Toshiba model SXT-6-11, Toshiba Corp, Japan) was used with a 80 kilovolt peak at 2 milliamperes. The amount of fluoroscopic time was recorded for each operative procedure. At the end of the 6-month period, the chips were collected and evaluated for radiation dosage using Toledo TLD reader (Model 454, Vinten Instruments, UK) with appropriate non-exposed and standard exposed chip controls.

We also studied the radiation scatter within the operating theatre during use of the image intensifier. A tissue equivalent Perspex phantom (Radcal Model 20CT Body Phantom) was used and the radiation measured using a Victoreen dose-rate meter model 491 during operation of the C-arm in both vertical and horizontal positions.

RESULTS

Table I shows the cumulative radiation dosage to the surgeon over the 6-month period. The International Committee for Radiological Protection (ICRP) recommended maximum exposure dosage per year is shown for comparison in Table II. The radiation dosage fell well within the ICRP recommendations. The surgeon's right hand was exposed to a much higher dose of radiation than the left as this was the dominant hand which was used to hold the drill during free-hand distal targeting for locked nailing procedures.

Table III shows the types of procedures carried out over the study period and the mean fluoroscopic time utilised per procedure. The radiation dosage per procedure is proportional to the fluoroscopic time utilised, which itself is a reflection of the degree of difficulty of the surgical procedure.

Table IV shows the radiation scatter measured during use of the image intensifier at various positions (Fig 1) within the operating theatre. The image intensifier was positioned in the vertical position with radiation source below the perspex phantom and in the horizontal position with the radiation source on the side of the operating field. The radiation was found to be negligible behind the concrete walls (position 6) and behind

Table I – Cumulative radiation dosage to the surgeon over 6 months.

Site	Radiation (mSv)	
Eyes	0.834	
Thyroid	0.794 (no shield)	0.508 (shielded)
Waist	0.857 (no apron)	0.476 (with apron)
Hands	0.699 (right)	0.143 (left)
Feet	0.587 (right)	0.635 (left)

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Table II – International Commission for Radiation Protection (ICRP) recommended dose limits for radiation workers and for the general population.

Applications	Dose limits – Radiation workers	Dose limits – Public
Annual effective dose	20 mSv/year (averaged over 5 yr)	1 mSv/year
Annual equivalent dose in:		
Lens of eye	150 mSv	15 mSv
Skin	500 mSv	50 mSv
Hand/feet	500 mSv	

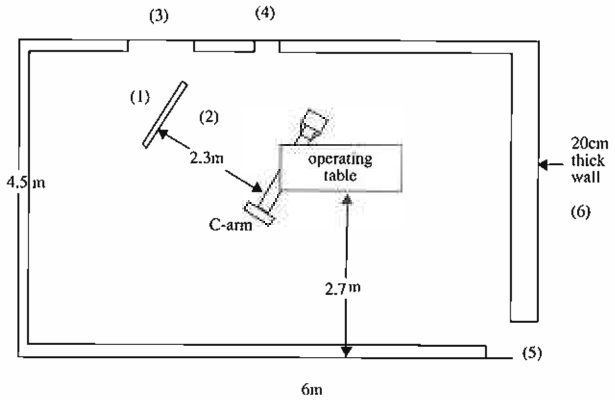
Table III – Types of procedures carried out and the mean fluoroscopic time per procedure.

Procedure	No.	Mean fluoroscopic time per procedure (min)
Dynamic hip screw	13	1.26
Femoral nail	2	1.33
Locked femoral nail	3	7.60
Tibial nail	1	0.75
Locked tibial nail	1	2.00

Table IV – Radiation scatter within operating theatre

Site	Radiation (μSv/Hr)	
	Vertical	Horizontal
Behind lead screen (1)	0.8	0.8
In front of lead screen (2)	14.0	24.0
Behind wooden door (3)	6.0	8.0
Behind window panel (4)	16.0	14.0
Access way (5)	5.0	30.0
Scrub area (behind concrete wall) (6)	0.2	0.2

Fig 1 – Plan of the orthopaedic operating theatre. The radiation levels at the 6 numbered positions are shown in Table IV.



the lead screen (position 1). These were the common positions that the operating theatre staff seek shelter when the image intensifier is in use. A window (position 4) in the concrete theatre wall covered over by wooden panelling was found to transmit a fair amount of radiation. Personnel standing behind this window were afforded a false sense of safety.

Table V shows the radiation scatter during use of the image intensifier in the vertical position (Fig 2) and the horizontal position (Fig 3). The radiation measured at 100 cm from the patient was markedly reduced from that measured at 50 cm. This reflects the inverse square law that governs the drop in radiation with distance from the source. The radiation scatter is higher when the C-arm is used in the horizontal mode compared to the vertical mode.

Table V - Angular distribution of dose rate at 50 cm and 100 cm from the phantom, with the C-arm used in the vertical mode and horizontal axis.

Angle	Radiation rate (mSv/Hr) 50 cm	100 cm
(A) C-arm in vertical mode		
45°	0.16	0.07
90°	0.19	0.1
135°	0.2	0.04
(B) C-arm in horizontal mode		
45°	0.16	0.1
90°	>0.2	0.15
135°	0.08	0.06

DISCUSSION

Most personnel who work with radiation use dosimeter badges to monitor radiation dosage received. Once they have exceeded the ICRP (International Committee on Radiological Protection) recommended maximum dosages[1], a thorough examination is

Fig 2 – Position of the image intensifier (I) in the vertical position. Radiation is measured at 50 cm and 100 cm from the phantom at 3 positions – 45°, 90° and 135°.

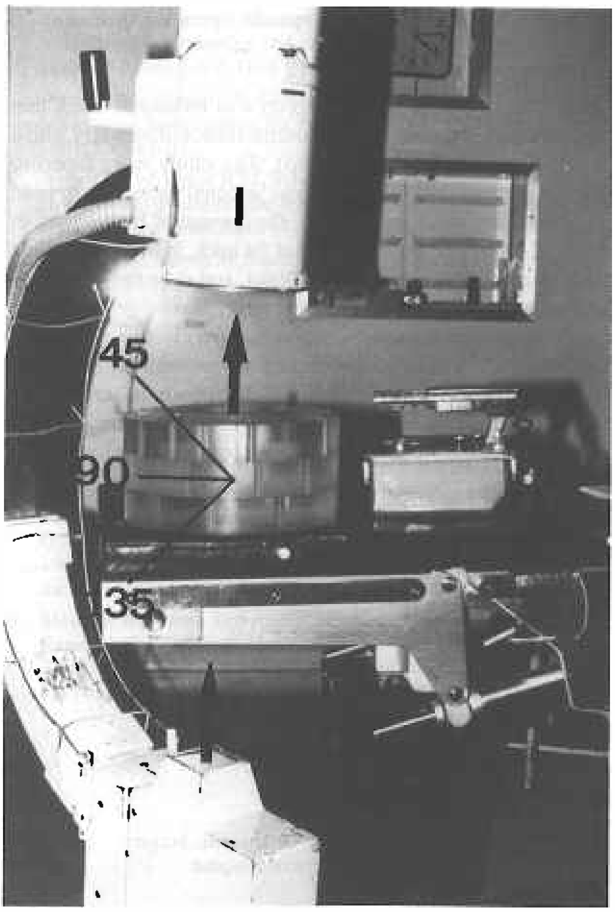
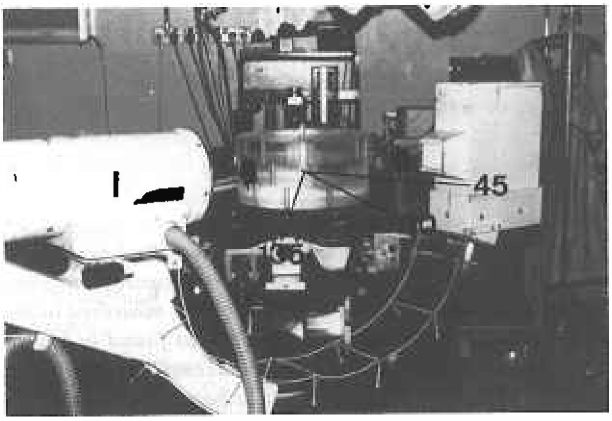


Fig 3 - Position of the image intensifier (I) in the horizontal position. Radiation is measured at 50 cm and 100 cm from the phantom at 3 positions – 45°, 90° and 135°.



usually conducted by the regulatory body, of the design and operational aspects of protection in the installation concerned. Operating room staff who use the image intensifier routinely, unfortunately, do not monitor their radiation exposure. There is some concern among orthopaedic surgeons, scrub nurses, anaesthetists and circulating nurses about the amount of radiation that they are exposed to in the course of work. This is especially so now that there is an increasing preference for the use of image intensifier guided procedures in orthopaedic work, such as the use of closed locked intramedullary nails and percutaneous cannulated screws for fixation of fractures. These procedures require the surgeon and his assistants to spend a considerable amount of time in close proximity to the radiation beam. We feel that OT staff should be considered as radiation workers if they are routinely and deliberately exposed to the use of X-ray imaging equipment in the course of their work. The same protection guidelines must apply to them so that they may be protected from unacceptable radiation dosages. The data from this study show that the radiation dosage of a surgeon in a busy orthopaedic unit is well within the ICRP recommended guidelines. Other researchers have also shown that the radiation dosage from fluoroscope guided procedures in orthopaedic surgery is within acceptable limits[2-4]. This should be reassuring to the surgeons and other operating room personnel.

However, we found that the radiation measured behind the thyroid shields and the lead aprons were higher than expected. The shields and the aprons were checked with the radiation doserate meter and the radiation measured behind them were actually negligible. We believe that the radiation that was picked up behind the protective wear by the lithium fluoride chips was due to lateral motion of the surgeon in relation to the radiation beam during screening procedures or due to improper wearing of the thyroid shield. One common error was to wear the thyroid shield too loosely around the neck, resulting in the shield sagging downwards and exposing the thyroid. The surgeon and his assistants must be reminded to face the operation site squarely during use of the image intensifier.

The radiation survey showed that there is adequate protection behind the lead screen and the concrete walls of the operating room. However, as this is peculiar to the design of the operating room, we recommend that radiation surveys be carried out in rooms which use an image intensifier. Not only is this practice reassuring to the staff but it is also a standard practice for all work environment in which radiation equipment is used.

Although this study showed radiation dosage to staff from the use of an image intensifier to be within safe limits, the ICRP acknowledges that the long-term effects of any additional amounts of radiation from non-natural sources are not known. Hence all efforts should be made to reduce this radiation to a minimum. As an orthopaedic surgeon will continue to use the image intensifier for several decades of his professional career, it is important that proper use of protective shielding be encouraged. This study showed that the surgeon's dominant hand, eyes and thyroid region were exposed to the highest amount of radiation. Similar findings were noted by Miller[3] and Levin[2]. Yet few surgeons use lead glass eyewear, thyroid shields or leadlined gloves. Most find them cumbersome and wear only a lead apron. Consideration should be given to their use whenever appropriate.

It is also important to take proper care of the lead apron. Crumpling of the lead apron will break the integrity of the lead fibre shielding. Therefore the lead apron should be properly hung up after use. The integrity of the lead apron should be checked regularly and this can be done easily by taking a radiograph of the apron. Cracks in the apron will show on the radiograph.

There are some good practices that the surgeon can adopt to reduce the radiation to himself and his assistants. The simple act of standing back during screening greatly reduces radiation exposure because of the inverse square law. The radiation scatter drops by a square of the distance the surgeon positions himself from the operation side. The amount of radiation scatter from the primary beam can be reduced by the positioning of the image intensifier and the surgeon should be aware of this. The radiation back scatter is greatest when working with the femur because of the bulk of the thigh. Giachino and Cheng[5] had shown that positioning the C-arm with the radiation source directed from lateral to medial when used in the horizontal mode increases the back scatter from the thigh to the surgeon. The preferred position should have the radiation source directed from medial to lateral, with the bulk of the thigh attenuating the scatter. Mahaisavariya et al[6] had described an innovative method of hanging a lead apron between the C-arm and the surgeon so as to reduce the back scatter to the surgeon.

Sanders[4] found that the greatest amount of radiation was recorded during femoral nailing procedures that involved distal locking. Our cases, although limited in number, concur with this. The surgeon's hands are most vulnerable during the insertion of the distal locking screws because of their close proximity to the radiation beam. Various devices can be used to reduce the radiation to the hands such as radiolucent drives for the drill or distal targeting devices[7]. Radiation dosage has also been shown to correlate with the length of time the fluoroscope was used. One study[4] showed that ideally, a surgeon should not use more than 1.7 minutes of fluoroscopic time. Therefore complex fractures should best be delegated to experienced surgeons. The image-memory mode has been found to decrease the duration of fluoroscopic time by up to 60%. Use of real-time fluoroscopic screening should be discouraged.

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