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Radiation exposure during fixation of femoral trochanteric fractures

Jagjit S Sidhu, MBBS (S'pore), FRCS (Edin)
Orthopaedics Surgeon
General Hospital
Kuala Lumpur

Taiman Kadni, MSc. (Nuclear Tech)
Research
Nuclear Energy Unit, Puspati, KL.

Summary

Radiation exposure to the surgeon and patient was measured in 14 patients during internal fixation of trochanteric fractures of the femur. Dosimetry studies were also done to determine the directions of maximum scatter production. The results indicated that the standard lead apron suffices for adequate gonadal and bone marrow shielding but the surgeon is still exposed to significant radiation levels – to the extremities and neck. Based on these findings some recommendations for reduction of radiation exposure to the surgeon are presented.

Introduction

There is now widespread acceptance and increasing use of image intensified screening in a variety of orthopaedic surgical procedures. Concern over radiological effects and radiation health hazards prompted a study of 14 patients during internal fixation of tronchanteric fractures of the femur. It has been noted in recent studies that there is a reduction of radiation dose when the lateral view is effected with the radiation beam positioned horizontally and parallel to the patient and focused in a medial to lateral direction[1,2] but there are other workers who were unable to show similar results with such an arrangement.[3]

In the studies presented here we have highlighted the hitherto neglected factor of radiation leakage, besides scatter, and have also had occasion to use a novel method of measuring radiation dose to the surgeon's hands. Critical precautions are also identified that should be adhered to in positioning the fluroscopic beam to reduce radiation exposure to the surgeon.

Materials and method

Thin-layer lithium fluoride thermoluminescent dosimetry chips (TLD- powdered form encapsulated in discs, HARSHAW) rather than standard radiation badges were taped to various areas of the surgeon's person at the commencement of each procedure. Sterilised rings incorporating lithium floride were worn on each index finger in between two pairs of gloves. Exposure to the patient was monitored by a thermoluminescent dosimetry chip taped to the anterior aspect of the pelvis at the level of the symphysis pubis.

The radiation output of the image intensifier and background radiation were also similarly determined. In the two separate studies involving eight and six patients the surgeon retained the same discs throughout that particular study and at the end of these two studies, two batches of lithium flouride dosimetry chips were collected and analysed for radiation exposure at the Nuclear Energey Unit using a VICTOREEN TLD reader (Model 2800) with appropriate non-exposed and standard exposed chips. Lithium flouride chips were used because in personnel monitoring it has the great advantage that its response does not vary much with the energy of radiation, much less than that of a photographic emulsion and its sensitivity is adequate for most protection measurements.

A separate study to determine levels of radiation was conducted using the Philips BV C-arm image intensifier in real-time mode. The machine was operated at 80 kV peak and 2.5 to 3.0 milliamperes with intermittent on-off switching. In these studies, a tissue equivalent perspex phantom (10 x 20 x 15 cm) was utilised and radiation measures were made using a portable Beta-Gamma Doserate Meter (Model Nuclear Enterprises PDMI).

Results

Table 1 depicts the total radiation exposure to the surgeon at various anatomical sites detailed A to H during the two separate studies. The radiation output of the machine was 11.6 millisieverts/min and the total patient exposure (groin) in the first study of 8 patients was 8.9 mSv. The mean duration of machine use in the two studies was 4.95 min and 6.08 min respectively.

Table 1

Measurement of radiation exposure to the orthopaedic surgeon using image intensifier in the operative fixation of fractures

No. of Cases	Duration of machine use (min)	Exposure to the surgeon (μSv)							
		A	B	C	D	E	F	G	H
8	39.6	202	108	293	0	338	0	237	2136
6	36.5	49	89	142	0	147	14	321	71

A – forehead, B – thyroid, C – chest (external surface of protective lead apron), D – chest (under the lead apron), E – mid pelvis (external surface of protective lead apron), F – (under the lead apron), G – right index finger, H – left index finger. μSv – microsieverts (1mSv - 1 rem)

The dose measured beneath the lead aprons was negligible despite inflated results of radiation exposure in the mid pelvis of the surgeon involved in the second study. Overall both these studies revealed that surgeons received lower doses of radiation to the neck and forehead but in the first study the highest radiation exposure was recorded for the left hand whilst in the second it was the right hand though all the surgeons were right handed.

Table 2 reveals the tissue equivalent phantom data that reflects the underlying physics and geometric relationships of scatter production, besides the radiation leakage that contributes to the overall prevailing radiation dose. These readings were obtained at a radius of 0.5 metres from the centre of the phantom (in the horizontal plane) at various angles i.e. 0° to 315°. The energy response of the monitor calibrated against the secondary standard dosimeter at the Secondary Standard Dosimetry Unit is stated to be± 10% over the range of 40 keV to 1.25 MeV with build up (Ref. Figures 1 & 2).

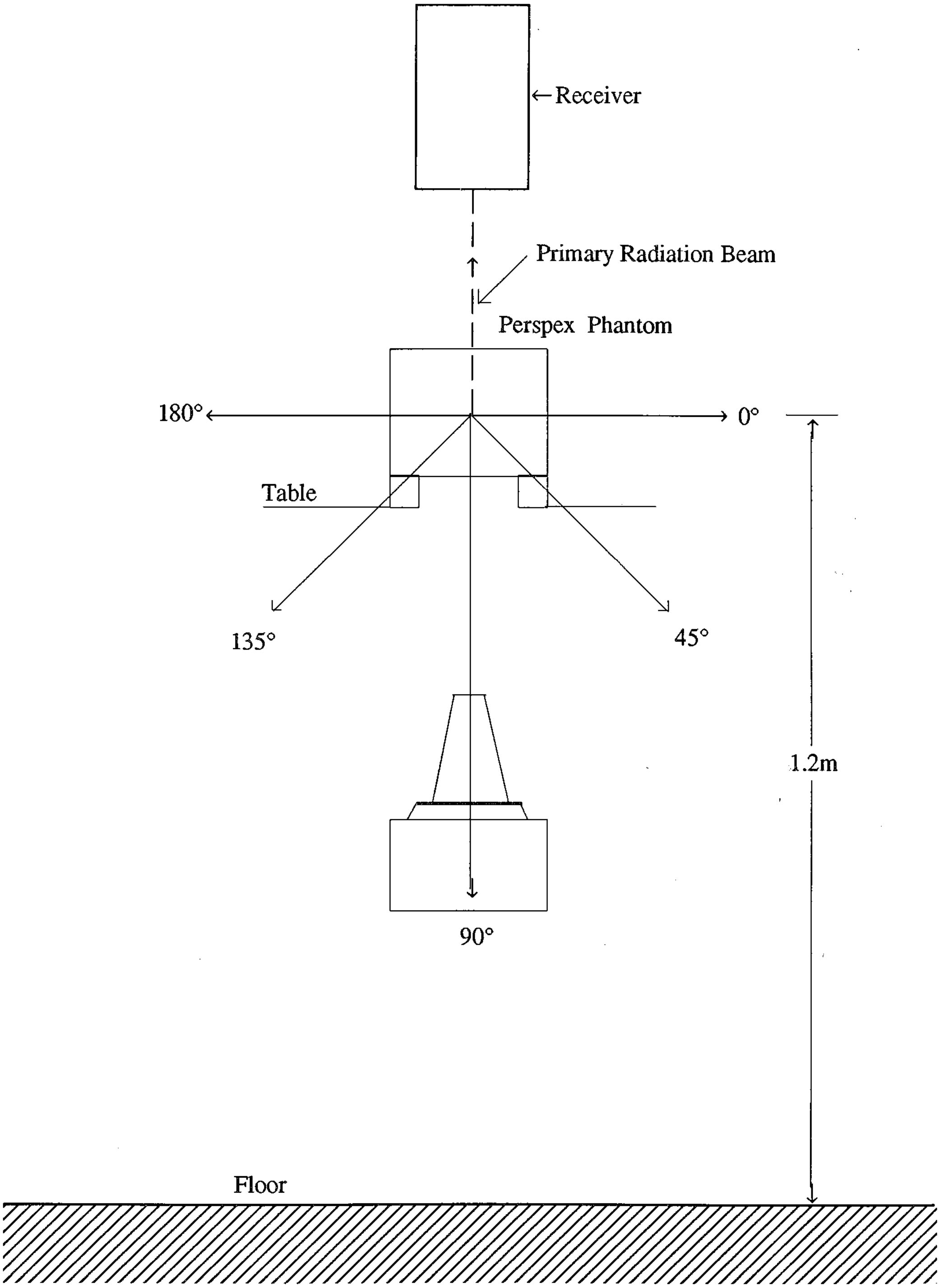

Fig 1:
The primary radiation beam is perpendicular to the table

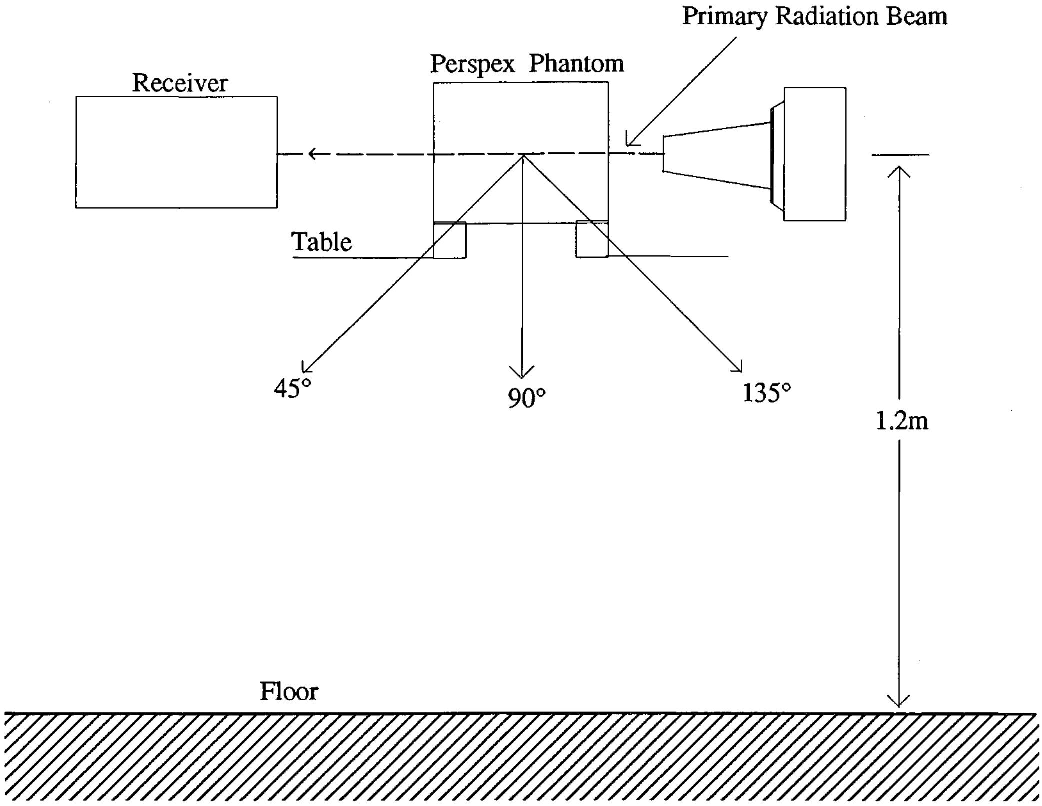

Fig 2:
The primary radiation beam is parallel to the table

Table 2

Radiation levels from scattered and leakage radiation of fluoroscopy unit at 870 kilovolt peak and 2.5 to 3.0 milliamperes measured at 0.5m distance from the centre of the perspex phantom (20 x 20 x 15cm^3) and 1.2m from the floor and at various angles. The radiation measurements were taken by using a portable Beta-Gamma Doserate Meter.

Angles from which measurements were made (degrees)	**Readings (μSv/hr)**	
	A	**B**
0	127	–
45	81	554
90	333	665
135	84	1551
180	152	–
225	105	–
270	380	–
315	105	–

Note: A – The primary radiation beam is perpendicular to the table.
B – The primary radiation beam is parallel to the table.

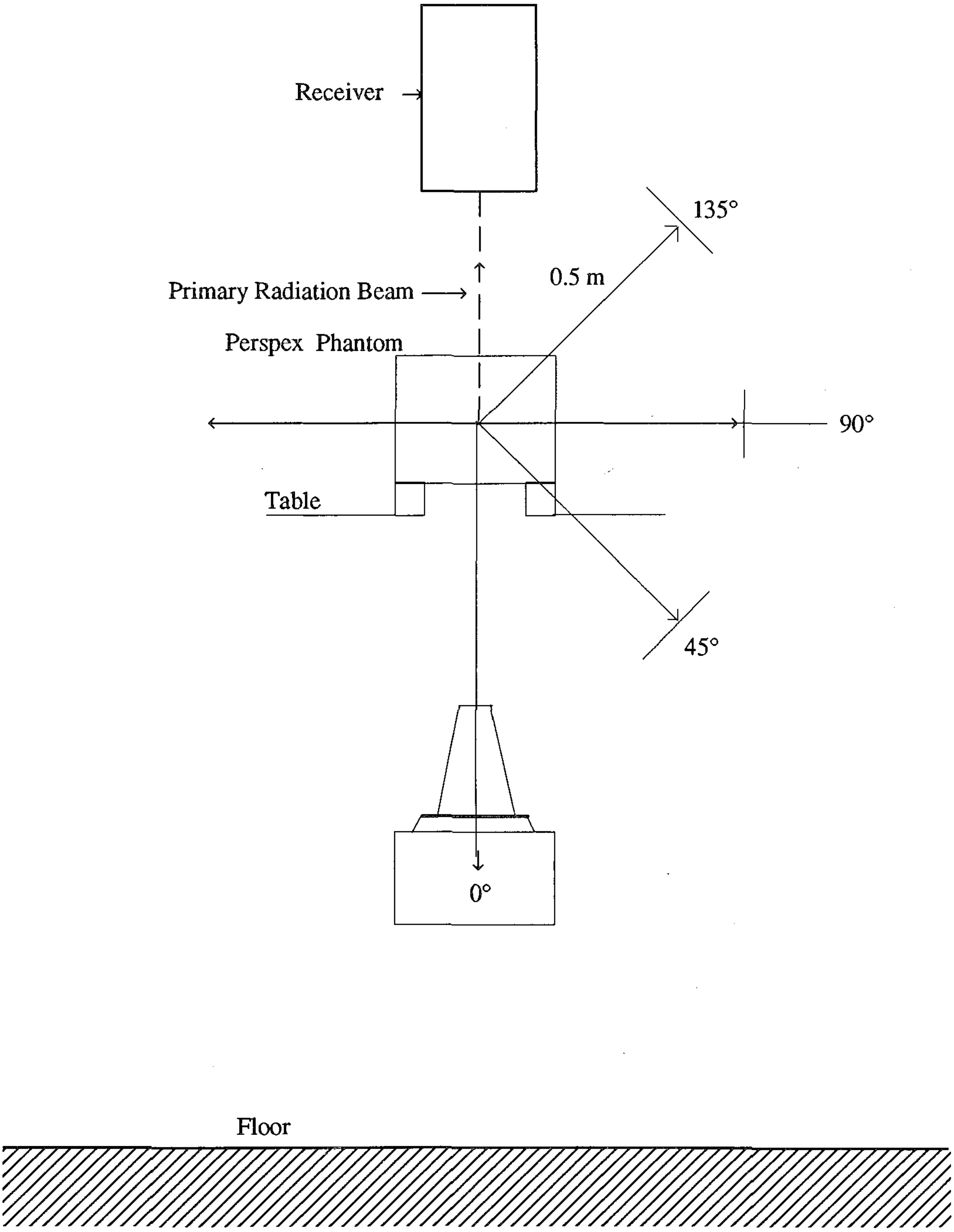

Fig 3:
The primary radiation beam is perpendicular to the table

Table 3 depicts the radiation levels (from both scattered and leakage radiation) of the fluoroscopy unit at 80 kV peak and 3.1 mA measured at 0.5m distance from the centre of the perspex phantom. These readings were obtained in the vertical plane parallel to the primary radiation beam which is focused from an under couch tube i.e. vertical posterior-anterior position (Figure 3).

Table 3

Angles from which measurements were made (degrees)	Readings (μsV/hr)
45	475
90	333
135	157

Discussion

There has been increasing concern over the widespread and occasionally nonchalant use of image intensifiers in various orthopaedic procedures ranging from closed manual reduction of fractures to open reduction and internal fixation of inter trochanteric fractures. Percutaneous procedures including angiography, transhepatic cholangiography and nephrolithotomies also entail the prolonged use of fluoroscopic guidance of instruments. Surgeons without an awareness of radiation protection may feel that the obvious needs of the patient outweighs a palpable but future risk of radiation injury to themselves. Table 2 indicates that with radiation beam parallel to the table the radiation levels are highest closest to the source of primary beam radiation i.e. at the 135° position (refer to column B). There is no doubt that there is a significant contribution from radiation leakage around the tube itself – besides the increased scatter. The radiation levels with the primary beam perpendicular to the table (column A) are rather peculiar. We would expect an equivalent radiation dose at all equidistant points from the centre of the irradiated phantom. This was not the case because the intensity of the X'ray beam which leaves the X'ray tube is not uniform throughout all portions of the beam (the heel effect)[6] and further there is a possibility that the intervening arm of the image intensifier in the vertical position may contribute to increased scatter at the 90° position.

Table 4

Maximum permissible dose equivalent for occupational exposure[5]

Body Part	Dose*
Whole-body, critical organs organs, gonads, lens of eye, bone marrow	5 rems in any one year (Prospective annual limit) 10-15 rems in any one year (retrospective annual limit) (N-18) x 5 rems (long-term accumulation to age/N/years)
Skin	15 rems in any one year
Hands	17 rems in any one year (25/qtr)
Forearms	30 rems in any one year (10/qtr)
Other organs, tissues and organ systems	15 rems in any one year

*Rem – roentgen-equivalent-man

Source: National Council on Radiation Protections & Measurements. (Washington 1971)

The data in these studies indicate that the standard lead apron suffices for adequate gonadal and bone marrow shielding. The inflated results of total exposure of 14 μSv underneath the lead apron of the surgeons in the second study could probably be due to lateral movement of the surgeon in relation to the radiation beam, as when occasionally, the view of the TV monitor is obscured by part or a portion of the intervening arm of the image intensifier in the vertical position. Further it was determined that there were no violations of the integrity of the marked lead aprons that were used continuously through the study. The main concern here is for the head, neck or hands because they are always unprotected, although the extrapolated annual cumulative radiaiton exposure based on 5 cases per month is below the maximum permissible dose equivalents as shown in Table 4. With numerous repeated exposure it is possible that the greatest risk would be the development of cataracts, the induction of thyroid neoplasms and skin cancers (Table 4). Image-intensified screening is now so commonly used that the frequency of usage would add to the radiation dose and thus reduce the margin of safety. Further, an orthopaedic career spanning many decades with extensive use of the image intensifier would only serve to accumulate added risks.

Table 3 confirms what other workers in this field have shown. It is because of primary beam attenuation that the production of scatter radiation is much higher at the entrance tissues than at the exit tissues of the patient. Therefore caution is advised when overhead tubes are used. In fact, in comparison with an under couch set i.e. when the tube is beneath the table the dose can be 250 times higher to the whole body[7]. With a C-arm, operator exposure varies with the orientation of the unit. It has been documented that oblique flouroscopy results in higher kVp and/or mA levels, which increase tube output and therefore scatter radiation levels. When the image intensifier is swung away from the operator during manipulations, as in closed manual reductions of fractures, under fluoroscopy, the X'ray tube and therefore the entrance surface of the beam swings out from under the patient towards the surgeon again increasing exposure (Radiology June 1986). Cognizance must be taken of the fact that the higher readings noted at the 45° position in Fig. 1 could have been due to tube leakage, besides increased scatter.

To minimize exposure it would be prudent to:

a. adhere to the routine common-sense precautions of standing back and removing the hands from the primary beam during screening (inverse square law of radiation)

b. adopt an arrangement whereby whilst obtaining the lateral view, the tube should be between the patient's legs although the radiographers in the hospital employ the opposite position for convenience

c. do regular upkeep and maintenance of the machine which is usually trundled about and abused when there are fuzzy and 'snowy' pictures on the screen

d. have careful collimation of the beam and adequate radiation shielding of the fluoroscopic tube housing to reduce leakage.

e. reduce screening time. It has been shown that such a reduction (of screening time) could be brought about by routine use of a memory mode.

There are also lead-glass eyeshields, thyroid shields and radiation-attenuating surgical gloves available in the market. In fact anthropomorphic phantom studies have shown that the scatter that reaches the operator's head and neck radiates from the side (lateral aspect) and upper most surface of the patient and that if these surfaces could be shielded by contiguous lead strips without impeding access to the operating field, a significant reduction of scatter may be obtained.

In conclusion, we feel that there should be emphasis on suitable training and awareness of radiation hazards and regular detailed monitoring of radiation dose to the operator to identify high risk situations and to effect appropriate measures; recommend changes of equipment and technique that would reduce radiation levels.

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