Radiation Exposure During Fixation of Femoral Trochanteric Fractures

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ABSTRACT: The escalating concern over possible associated radiation health hazards has prompted a study of 14 cases during inserting of implants for fracture neck of femur. Using thin layer lithium fluoride disc (LTD) radiation exposure to the surgeon during image intensified screening were done. Directions of maximum scatter radiation using tissue equivalent phantom models, leakage from the tube housing and the integrity of the standard protective apron common worn during fluoroscopy were done. Dosimetry studies also done to determine the optimum positioning of the fluoscopic beam to provide the lowest levels of scatter radiation.

INTRODUCTION

There is now widespread acceptance and increasing use of image intensified screening in a variety of orthopaedic surgical procedures. An escalating concern over radiobiological effects and radiation health hazards has prompted a study of 14 patients during open reduction and internal fixation of trochanteric 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 used a novel method of measuring radiation dose to the surgeon's hands and critical precautions are also identified that should be adhered to in positioning the fluoroscopic beam to reduce radiation exposre to the surgeon.[4] We believe that these should form the basis of local ground rules in the operating threatre.

MATERIALS AND METHODS

Thin-layer lithium fluoride thermoluminescent dosimetry chips (TLD-100 powder, HARSHAW) rather than standard radiation badges were taped to various areas of the body at the commencement of each procedure. Sterilised rings incorporating lithium fluoride were worn on each index finger in between two pairs of gloves. Exposure to the patient was monitored by a TLD taped to the anterior aspect of the pelvic at the level of the symphysis pubis.

The radiation output of the image intensifier and background radiation were also similarly determined. In the 2 separate studies involving eight and six patients the surgeon retained the same discs throughout that particular stdy and at the end of these 2 studies 2 batches of lithium fluoride dosimetry chips (TLD) were collected and analysed for radiation exposure at PUSPATI (Nuclear Energy Unit) using a VICTOREEN TLD reader (Model 2800) with appropriate non-exposed and standard exposed chips. Lithium fluoride chips were used because in personnel monitoring it has the great advantage that its response does not much with the energy of radiation, much less than that of a photographic emulsion and it is approximately tissue equivalent and shows a linear response to doses of up to 10 Gy.

A separate study to determine levels of scatter radiation was conducted using the Philips BVC C-arm image intensifier in real-time mode. The machine was operated at 80 KV pek and 1.5 milliamperes with intermittent on-off switching. In these scatter studies, a tissue equivalent perspex phantom (20 x 20 x 15 cm^3) was utilised and radiation measureements were made using a portable Beta-Gamma Doserate Meter (Model) Nuclear Enterprised (PDMI).

RESULT

Table 1 depicts the total radiation exposure to the surgeon at various anatomical sites detailed A to H during the 2 separate studies. The radiation output of the machine was 11.6 mSv/min. and the

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	Total
8	39.6	202	108	293	0	338	0	237	2,136	3,314
6	36.5	49	89	142	0	147	14	321	71	833

*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 = mid pelvis (under the lead apron), G = right index finger, H = left index finger.
μSv = microsieverts (10 μSv = 1mrem).

TABLE 2
Levels of Scattered Radiation from Fluoroscopy Unit at 80 kV Peak and 1.5mA Measured at 0.5 m Distance from the centre of the Perspex Phantom (20 x 20 x 15 cm^3) and 1.2 m from the Floor and at Various Angles. The Radiation Measurements were Taken by Using a Portable Beta-Gamma Doserate Meter, Model Nuclear Enterpeises PDM 1.

Angle from which measurements were made (degree).	Readings (μSv/hr)	
	A	B
0	50	–
45	35	170
90	70	250
135	60	600
180	70	–

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

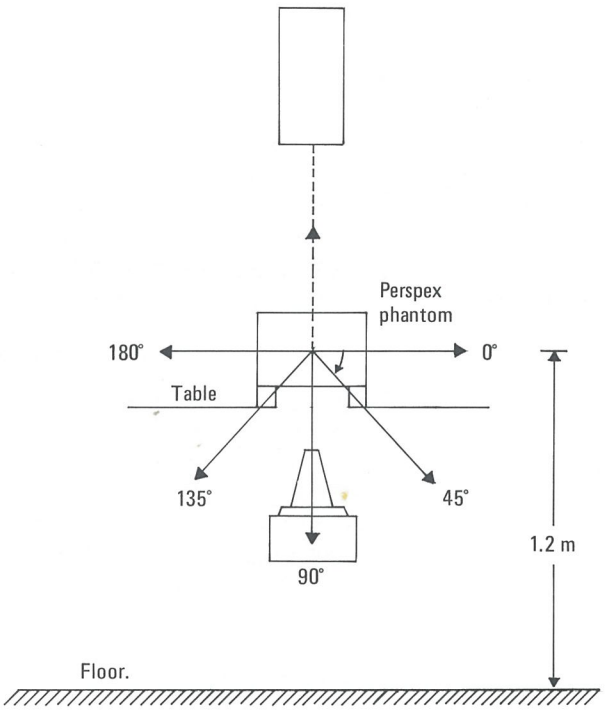

Fig. 1 The primary radiation beam is perpendicular to the table.

total patient exposure (groin) in the first study of 8 patients was 8.90 mSv. The mean duration of machine use in the 2 studies was 4.45 min. and 6.08 min. respectively.

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 low 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 study 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. In Figure 1 with the primary radiation beam focused from an undercouch tube (i.e. vertical posterior-anterior position in relation to the patient's proximal femur most of the scatter radiationis towards the feet of the surgeons. The corollary with an over couch tube would tend to scatter radiation towards the eyes and neck of the surgeon.

Figure 2 – shows the set-up with the radiation beam parallel with the table and the results in table 2 reveal that the largest amount of scatter radiation was at the 135 position.

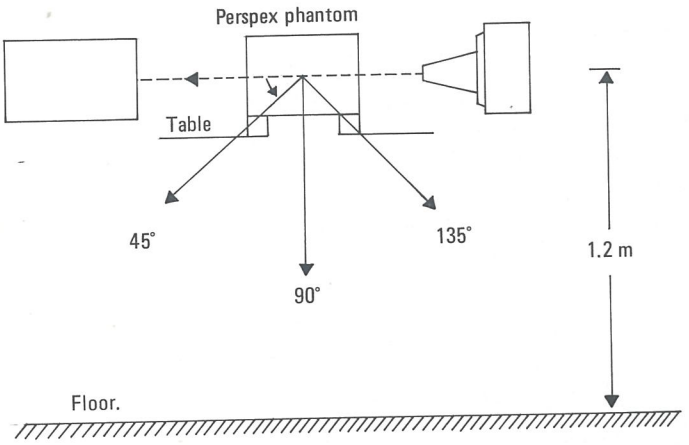

Fig. 2 The Primary radiation beam is parallel with the table.

DISCUSSION

There has been escalating concern regarding the widespread and even non chalant use of image intensifiers in various orthopaeddic procedures ranging from closed manual reductions of fractures, closed nailing of long bone fractures to open reduction and internal fixation of intertrochanteric fractures. Percutaneous procedures including angiography, transhepatic cholangiography, and nephrotolithotomies also entail the prolonged use of fluoroscopic guidance of instruments.

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 uSv underneath the lead apron of the surgeon 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 throughout the study. The main concern here is for the head, neck or hands because they are always uprotected, although the extrapolated annual cumulative radiation exposure based on 5 cases per month is way below the maximum permissible dose equivalents as shown in table 3.[5] With numerous repeated exposure it is possible that the greatest risk would be the development of cataracts, the induction of thyroid neoplasma and skin cancers. 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 decaded with extensive use of the image intensifier would only serve to accumulate added risks.

The results of Table 2 only confirm 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 over head tubes are used. In fact, in comparison with an under cough set the dose can be 250 times higher to the hands, 100 times higher to the eyes and 35 times higher to the whole body[6] (Statement from 1985 Meeting of the ICRP). With a C-arm, operator exposure varies with the orientation of the unit. It has been documented that oblique fluoroscopy results in higher kVp and/or mA levels, which increase tube output and therefore, scatter radiation levels, when the image intensifier is swung away

TABLE 3
Maximum Permissible Dose Equivalent for Occupational Exposure

Body Part	Dose*
Whole-body, critical organs: gonads, lengs of eye, bne 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 gge/N/years)
Skin	15 rems in any one year
Hands	75 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

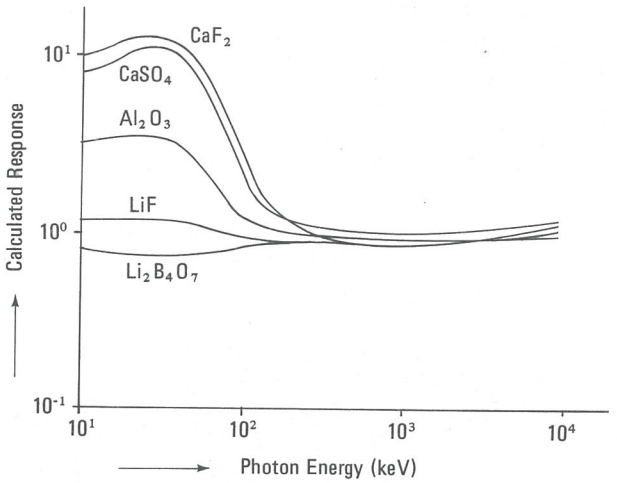

Fig. 3 Theoretical sensitivity of several thermoluminescent phosphors.

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.[7]

Cognizance must be taken of the fact that the higher readings noted at the 135 position in Figure 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 low of radiation);

b) adoption of an arragement whereby whistle 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) regular upkeep and maintenance of the machine which is usually trundled about and abused when there are fuzzy and *"snowy"* picture on the screen;

d) careful collimation of the beam;

e) reduction of screening time would all help. It has been shown that such a redduction (of screening time) could be brought about by routine use of a memory mode.[3]

Their a also available lead-glass eyeshields, thyroid shields and radiation attenuating surgical gloves in the market. In fact antropomorphic phantom studies have shown that the scatter that raches 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.[7]

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