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ORIGINAL STUDY

Exposure of the thyroid to radiation during routine orthopaedic procedures

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The availability and usage of portable image intensifiers has revolutionised routine orthopaedic practice. Extensive use of fluoroscopy however may result into significant radiation exposure to operating staff. An accumulated dose of 65 µSv per procedure over long exposure has been reported to increase the risk of thyroid cancer. The present prospective study aimed at measuring the scattered dose to the thyroid using an Unfors EDD dosimeter during DHS/IMHS for fractures of the neck of the femur and IM nailing for long bone fractures. In 32 procedures, the dose of 65 µSv was exceeded 13 times ; 8 times during DHS/IMHS and 5 times during IMN. The average thyroid dose was 142 µSv during IMN and 55 µSv during DHS. Only 9 of the total 223 (4%) theatre personnel were using a thyroid shield in spite of its availability. These results suggest that the thyroid is frequently exposed to potentially harmful radiation during these procedures. Strict inclusion of a thyroid shield as a part of routine radiation protection is recommended.

Keywords : radiation exposure ; thyroid shield ; dosimeter ; scattered radiation ; image intensifier.

INTRODUCTION

The availability and usage of portable image intensifiers has revolutionised routine orthopaedic practice. Many orthopaedic procedures have become simpler, easier, less invasive and less time consuming. The variety of procedures for which fluoroscopic screening is used, continues to increase. Studies have shown that the risk to patients following exposure to radiation through medical imaging procedures is minimal (*8*) but these procedures may result in a high level of radiation exposure to the surgeon and the operating-theatre staff. Occupational radiation exposure and associated radiogenic risks to the orthopaedic surgeon and assisting staff are of increasing interest and importance (*1, 2*).

The radiation exposure in the theatre during orthopaedic procedures has been investigated extensively in recent years (*2, 3, 10, 13, 14*). The precise risk of scattered radiation to the thyroid is still unknown. An accumulated dose of 65 µSv per procedure over a long period has been reported to increase the risk of thyroid cancer, many years later (*5*). Previous studies have shown that it is possible to exceed this dose during various orthopaedic procedures (*2*). Although thyroid shields are extensively available, most orthopaedic surgeons rarely use them. The present study was aimed at

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measuring the scattered dose to the thyroid accurately while performing either a Dynamic Hip Screw (DHS) or Intra-medullary nailing (IMN) and thereby assesses the need to wear a thyroid shield for the operating surgeon and other theatre personnel.

MATERIALS AND METHODS

A prospective study of 32 consecutive procedures (31 patients) was carried out at our hospital from November 2003 to March 2004. For inclusion, the procedure had to be a DHS, intra-medullary hip screw fixation (IMHS) or IM nailing. These three procedures were selected for the study because they are most commonly performed at an average district general hospital (DGH) and often require a high number of images.

The EDD Unfors dosimeter was used for the study. It has a sensor that detects scattered radiation and measures the total exposure dose and duration of the exposure at the end of the procedure. When worn during a procedure, it provides the wearer with continuous information about the dose rate that he/she is receiving, whereas TLDs or film badges only provide retrospective information of accumulated dose. The Unfors sensors have been specially designed to meet the needs of real-time dose measurements on patients. For the study, the dosimeter sensor was clipped in front of the thyroid gland. Both, the total dose of radiation and the tissue specific exposure dose were measured from this dosimeter. Measurements were also obtained from the mobile C-arm fluoroscope unit (Siremobil 2000-2/23 cm), which calculated the total number of images, the total dose and the duration of the radiation for each procedure. The radiation unit was measured in CentiGray.centimeter^2 (cGy.cm^2) on the C-arm unit and in MicroSievert (μSv) on the dosimeter [1 cGy = 1000 μSv]. Other factors including the patient demographics, the grade of the surgeon, the total number of theatre personnel wearing a lead gown and/or a thyroid shield and the duration of surgery were also recorded.

RESULTS

Thirty two procedures were carried out in 31 patients ; one patient had bilateral femoral fractures. The average age group of the study was 70.3 years, ranging from 17 to 98 years, the median age being 84. There were 12 men and 19 women. Twenty four patients had a fracture of the neck of the femur ; 21 were treated with a DHS and 3 with an IMHS. Seven patients had fractures of long bones (6 unilateral femoral, 1 bilateral femoral, 1 tibial), which were treated with intra-medullary nailing (table I).

Of the 32 procedures, 7 were carried out by consultants, 22 by specialist registrars (SpR) and 3 by Senior House Officers (SHO) (fig 1).

All procedures

The average number of images taken during these procedures was 63.7 with a median of 52 for each procedure (range : 5 to 268) (fig 2). The average duration of exposure to radiation was 0.9 minutes as recorded on the dosimeter, with a range from 0.1 to 3.9 minutes. The average dose of radiation recorded by the image intensifier was 261.43 cGy.cm^2 per procedure (range : 5 to 1,320). The scattered radiation dose to thyroid was 76.85 μSv on average, however the median was 54 mSv (range : 0.034 to 384.6) (fig 3) (tables I & II).

DHS and IMHS

In the 24 procedures performed, the average number of images was 54. The mean duration of radiation was recorded as 0.64 minutes and the average total dose of radiation was 231.75 cGy.cm^2. The mean thyroid dose was 55.18 μSv.

IM nailing

In the 8 procedures performed, the average number of images was 90. The mean total duration of radiation was recorded as 1.73 minutes and the average total dose of radiation was 349.88 cGy.cm^2. The average radiation dose to the thyroid was 141.87 μSv.

The total dose of radiation recorded on the image intensifier and the scattered dose measured on the thyroid dosimeter were significantly higher during IM nailing as compared to DHS surgery. Similar findings were made irrespective of the grade and experience of the surgeon. Out of the 7 procedures carried out by consultants, the

Table I. — This table shows the details of all procedures along with total number of images, total dose of radiation and the thyroid exposure dose (Bil : bilateral, # : fracture, NOF : neck of femur, ST : subtrochanteric). *This case was excluded from the series due to incorrect readings possibly due to malfunctioning of the equipment

No	Age	Sex	Diagnosis	Procedure	No. of images	Total dose of radiation in μSv	Thyroid dose on dosimeter in μSv
1	**88**	**F**	**# NOF**	**DHS**	**23**	**389**	**67.17**
2	51	M	# NOF	DHS	96	462	42.7
3	52	F	# NOF	DHS	37	79	25.75
4	55	M	# NOF	DHS	27	92	54
5	**72**	**F**	**# NOF**	**DHS**	**69**	**189**	**190.1**
6	80	F	# NOF	DHS	69	360	21.3
7	80	M	# NOF	DHS	48	116	60
8	**84**	**M**	**# NOF**	**DHS**	**29**	**108**	**65**
9	**84**	**F**	**# NOF**	**DHS**	**95**	**432**	**164.4**
10	**85**	**F**	**# NOF**	**DHS**	**30**	**72**	**72**
11	87	F	# NOF	DHS	70	550	49.7
12	87	M	# NOF	DHS	19	83	12.14
13	87	F	# NOF	DHS	52	341	36.36
14	88	M	# NOF	DHS	24	108	42.79
15	**89**	**M**	**# NOF**	**DHS**	**60**	**242**	**89.29**
16	**89**	**F**	**# NOF**	**DHS**	**78**	**306**	**65.1**
17	90	F	# NOF	DHS	73	368	27.41
18	90	F	# NOF	DHS	52	157	21.99
19	91	F	# NOF	DHS	52	188	34.00
20	91	F	# NOF	DHS	51	134	55.59
21	98	M	# NOF	DHS	43	152	54.05
22	**83**	**M**	**Femur #**	**IM nailing**	**22**	**26**	**132.7**
23*	92	F	Femur #	IM nailing	42	145	15.65
24	**17**	**F**	**Femur #**	**IM nailing**	**51**	**321**	**384.6**
25	**20**	**M**	**Femur #**	**IM nailing**	**268**	**620**	**292.1**
26	**22**	**M**	**Bil femur #**	**IM nailing**	**88**	**1320**	**164**
27	**62**	**M**	**Femur #**	**IM nailing**	**100**	**285**	**116.9**
28	84	F	Tibia #	IM nailing	198	82	29.04
29	68	F	# NOF	IMHS	56	262	13.76
30	83	F	# NOF	IMHS	109	112	26.03
31	**87**	**F**	**# NOF -ST**	**IMHS**	**45**	**260**	**68.82**

average number of images taken was 95 with a measured thyroid dose of 77.17 μSv on average. In 22 procedures done by registrars, the average number of images taken was 61 with an average thyroid dose of 85.88 μSv. High radiation doses generally tend to reflect poor and excessive screening technique. However in our study this could be due to the fact that consultants were involved in more difficult procedures with complex fracture pattern and/or comminution (table III). The amount of screening also depends on the patient build and there can be considerable patient-to-patient variation in dose. In a few procedures, the number of images taken was low, although a high dose was recorded on the dosimeter. This could be as a result of the variation in the experience of the radiographers and possibly due to the use of continuous screening for free hand locking during IM nailing. However this variable was not included when the study was set up.

During these 32 procedures, the total number of individuals present in theatre was 223 (average : 7, range : 5 to 10 per case). Two hundred and seven were wearing a lead gown (92.83%) but only 9 were using a thyroid shield (4%) in spite of its availability (fig 4).

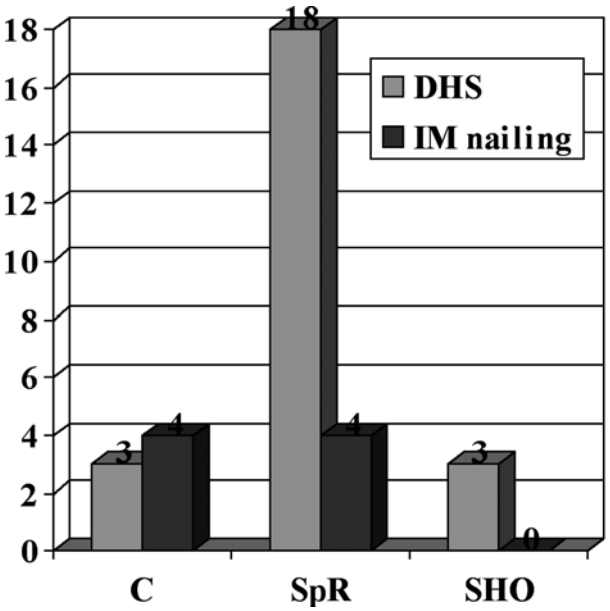

Fig. 1. — Grade of surgeon performing procedures (C : Consultant, SpR : Specialist Registrar, SHO : Senior House Officer).

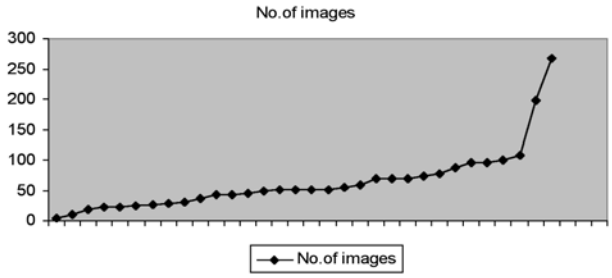

Fig. 2. — The graph shows the number of images taken during all procedures.

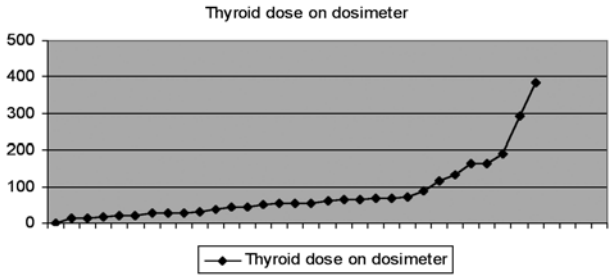

Fig. 3. — The graph shows the scattered dose of radiation measured on the dosimeter during all procedures.

DISCUSSION

The association of ionising radiation with development of neoplasia is a matter of great concern. Biological effects of radiation are greatest with rapidly growing tissues such as epithelium, bone, blood, gonads, thyroid, and in the foetus. The specific types of cancers associated with radiation exposure include leukemia, multiple myeloma, breast carcinoma, thyroid, lung and skin cancer. The accumulated chronic low dose exposure of these tissues to radiation can significantly increase the risk of cancer after 10-15 years.

Risk to the Thyroid

Exposure to radiation over many years promotes the development of thyroid carcinoma (*2*). Eighty five percent of the papillary carcinomas of the thyroid are radiation-induced. There is evidence that carcinogenic potential exists from low-dose, low-energy radiation (*4, 8, 12, 14, 15*). An accumulated dose of as little as 65 μSv, over multiple exposures can statistically increase the incidence of thyroid cancer, many years later (*2, 5*).

In our study the thyroid exposure dose was found to be higher than 65 μSv in most cases of IM nailing. It was also exceeded in some DHS procedures, although the mean was 55 μSv. The dose was exceeded 13 times in 32 procedures, 7 times during DHS (33%), 5 times during IM nailing (62.5%) and once during IMHS (33%), which is just under half the number of cases performed. These results suggest that the thyroid is frequently exposed to potentially harmful levels of radiation during routine orthopaedic procedures.

It is the scattered radiation that the theatre staff is most exposed to. The x-rays travel in a straight line from their source of origin and get scattered in their travel path. The beam intensity varies inversely with the second power of the distance from the tube. Accordingly, The ALARA principle (As Low

Table II. — Number of images, total dose and duration of radiation on the image intensifier, and scattered dose to thyroid gland as measured on dosimeter

Procedures	Number of images		Duration of radiation (In minutes)		Total Dose of radiation (cGy.cm^2)		Thyroid exposure Dose (µSv)	
	Range	Average	Range	Average	Range	Average	Range	Average
DHS / IMHS	19-109	54.4583	0.2-1.61	0.6421	72-550	231.75	0.034-190.1	55.1776
IM Nailing	51-268	90.375	0.1-3.9	1.7363	26-1320	349.88	15.65-384.6	141.87

Table III. — Comparison between the grades of surgeons. The thyroid dose and the number of images were found to be higher when a consultant was involved in the procedure

Grade of the surgeon	Number of procedures	Number of images		Duration of radiation (In minutes)		Total Dose of radiation (cGy.cm^2)		Thyroid exposure Dose (µSv)	
		Range	Average	Range	Average	Range	Average	Range	Average
Consultant	7	52-198	95.17	0.6-2.5	1.35	82-1320	439.67	27.41-164	77.17
SpR	22	51-268	61.54	0.2-3.3	0.91	26-620	241.77	12.14-384.6	85.88
SHO	3	24-52	35	0.3-0.6	0.43	108-188	134.65	0.034-64.18	35.67

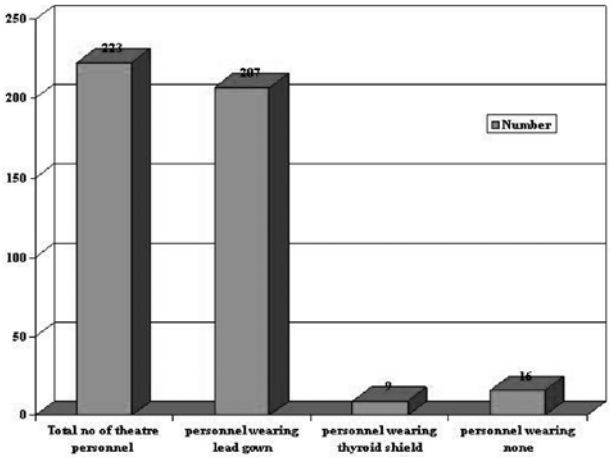

Fig. 4. — The figure shows that only 4% of the theatre personnel were using the thyroid apron in spite of its availability.

As Reasonably Achievable) has laid down three guidelines for the staff radiation protection (*6, 7, 9*). It states that the staff should position themselves out of the primary beam and the minimum distance between the X-ray source and the staff should be six feet (*1, 10*). These two objectives are practically unachievable in the operating theatre as the surgeon and the assistants have to position themselves very close to the fluoroscopic unit. Hence the third consideration becomes more important, that is the use of effective shields or barriers to prevent radiation exposure.

The IRR 99 guidelines (*16*) advise that all theatre staff should wear lead aprons during image intensifier screening. Although the lead gown is routinely worn as a part of most orthopaedic procedures, it does not cover the neck area and hence the thyroid gland. The dose limit recommended for the thyroid is 300 mSv per year. With the average dose of 65 microSv (= 0.065 mSv) it would require 4,615 procedures to reach that dose. Despite this low dose, since it is considered that there is no threshold for possible radiation injury, it is recommended to use the lead protection. In our study, only 9 out of 223 people were using a thyroid shield during fluoroscopic exposure. Although there will be different radiation exposures depending on the distance to the radiation source, it is still recommended to wear a thyroid shield for all personnel. The thyroid apron can decrease the amount of effective dose by 2.5 fold and there is almost 50% reduction in total exposure when it is used (*11*).

In previous studies, the exposure dose was found to be higher when a senior house officer was involved in the procedure (*3, 11*). This finding was not reflected in our study. Nowadays most junior surgeons are dealing with simpler procedures and

consultants are present during complex procedures. With the increasing emphasis on training, there is a greater involvement of the consultants with the trauma list where the majority of the cases are done. The experience of the radiographer also has a significant bearing on the total dosage and exposure.

The levels of occupational radiation exposure vary considerably with the type of fluoroscopically assisted procedure. The study has shown that it is possible to exceed the carcino-inductive dose during DHS and IM nailing. This low-dose exposure over many years could lead to the development of thyroid cancer. The strict inclusion of a thyroid shield as a part of routine radiation protection is recommended during these procedures. Further research is needed to assess the occupational risk of radiation and allow for the accurate assessment of hazardous doses to the sensitive tissues.

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