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TECHNICAL NOTE

THE USE OF LEAD APRONS IN CHEST RADIOGRAPHY

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Purpose: There is a general necessity to minimize patients' radiation dose. This may be done in a variety of ways including the use of localized shielding. It has been accepted practice for patients undergoing chest X-ray examination to wear lead half-aprons. Measurements were made to establish the necessity of such shielding when modern X-ray equipment with good collimation is used.
Methods: Thermoluminescent dosemeters and an ionization chamber were used to measure the entrance surface dose (ESD) at the centre of the X-ray beam and the exit dose. Dose at the locations of the ovaries were also measured.
Results: There was no difference between surface doses at ovary level recorded with and without the lead half-apron in place. The worst recorded case of dose received by the ovaries was 2.1% of the ESD in the field of view.
Conclusion: From the doses measured it was concluded that if the field of view is collimated to the waist then there is negligible radiation protection benefit from using a lead half-apron during chest X-ray examination.

Key words: chest X-ray; radiation dose; shielding; gonads; protection.

INTRODUCTION

The general consensus is that any exposure to ionising radiation carries a risk. Diagnostic radiology is the largest (87%) contributor to man-made ionising radiation [1], therefore any economical and socially acceptable means of reducing dose without compromising the diagnostic value of the procedure must be worth implementing. The International Commission on Radiological Protection (ICRP) recommend three principles for dose reduction namely: justification, limitation and optimization (the ALARA principle) [2]. The principle of optimization could be achieved, in addition to other factors, by considering time, shielding and distance from the source of X-rays. When examinations are carried out in close proximity to radiosensitive organs such as the eye, gonads and thyroid, local protection should be provided if practicable to these organs.

Chest X-ray examination is the most frequently performed radiological procedure, accounting for over 25% of all examinations in the U.K. [1]. Although the dose given in a chest examination is low, the fact that this examination is so common results in it contributing 2% of the collective U.K. population dose. For many years it has been accepted practice for patients undergoing chest X-ray examination to wear lead

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half-aprons (skirt) to minimize dose, in particular to the gonads. In order to be able to advise radiographers on the necessity and efficacy of using lead skirts now that X-ray beam collimation is much improved two studies were carried out.

MATERIALS AND METHODS

Chest X-ray examination

The X-ray unit used was a Dean D44. It is a single phase, full-wave rectified X-ray set, with a 1.0 and 2.0 mm focal spot X-ray tube and approximately 2.7 mm Al equivalent total filtration. Three chest X-ray views may be carried out (antero–posterior (AP), postero–anterior (PA), lateral) of which PA is by far the most common; so only the PA view was investigated in this report. A focus-to-surface distance of 180 cm and a field size at the skin of 32 cm × 40 cm was employed. Typically most chest X-ray examinations are carried out at either 60 kVp to 70 kVp or 125 kVp using an appropriate tube current and time. In this study the effect of different kVps was investigated.

Dose measurements

An anthropomorphic body phantom 'Rando phantom' (Alderson Research Laboratories, U.S.A.), was used to simulate an average adult patient. This is a widely used phantom for obtaining detailed dose distributions from external radiation sources. It has good dosimetric properties and its anthropometric characteristics are sufficiently close to those of a reference man [3]. The Rando phantom consists of 36 separate sections, sliced transversely at 2.5 cm intervals, numbered from the head downwards from 0 to 35.

Two different methods of dose measurements were employed in this study: thermoluminescent dosemeters (TLDs) and an ionization chamber. Lithium fluoride (TLD100, Harshaw, Reading, U.K.) TLDs were used to measure the entrance surface dose (ESD) and appropriate organ doses. The TLDs had a detection limit of 0.05 mGy. Dosemeters were placed at the centre of the X-ray beam at the entrance surface of slice 16 of the Rando phantom to measure the ESD. Other dosemeters were placed at the posterior surface, middle and anterior surface of slice 30 of the Rando phantom. It has been reported by Huda and Sandison [4] that slice 30 was the closest slice to the ovaries and therefore will give an approximate ovary dose. Approximately ten times the mAs was used, rather than the average value used in routine practice, so that a dose sufficiently above background could be recorded on the TLDs. No lead apron was used in this first study.

An MDH 2025 (20X5-3 ion chamber and converter connected to a 2025AC radiation monitor supplied by NE Technology Limited, Reading, U.K.) dosemeter was used in the second study to measure doses at different locations on the surface of the Rando phantom. The ion chamber has a detection range of 0.1 mR to 199.9 R (1 μGy–1.8 Gy). The chamber was placed at the following positions on the phantom: in the centre of the entrance surface (slice 16) of the X-ray beam, annotated A, at slice 30 (B), at slice 27 without lead apron (E) and with lead apron (0.25 mm lead equivalent) (E′) and at the centre of the exit surface of the X-ray beam at slice 27 (D). Slice 27 was used to obtain a slightly higher dose while still being near the level of the ovaries. The positions of the chamber are illustrated in Fig. 1. The TLDs and ionization chamber had calibrations traceable to primary standards.

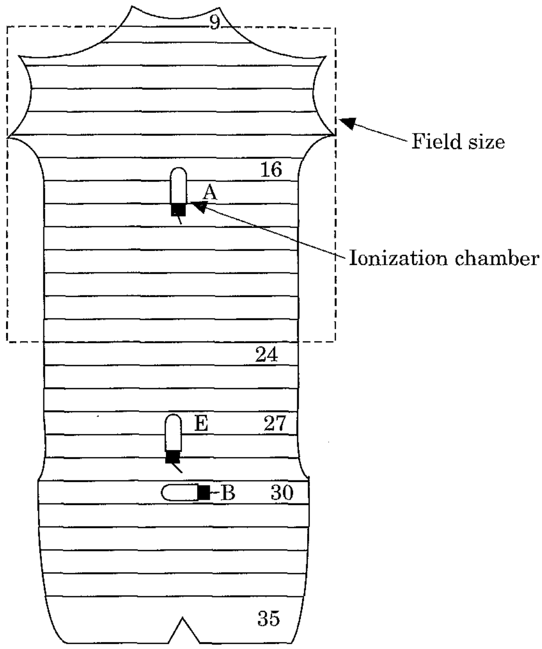

Figure 1. Schematic representation of the Rando phantom illustrating the various locations at which entrance surface doses were measured using an ionization chamber.

Table 1. Doses at the different locations measured using thermoluminescent dosemeters, where A is the estimated surface dose (ESD) in the centre of the field, B is the ESD and C is the exit dose both measured at the level of the ovaries and M is the dose in the middle of phantom at the approximate location of the ovaries

Settings		Doses (mGy)				Ovary dose as % of ESD
kVp	mAs	A	B	C	M	M/A × 100
70	160	5.560	0.100	0.088	0.098	1.8%
120	40	4.356	0.092	0.083	0.090	2.1%

RESULTS

Results of the two studies are presented in Tables 1 and 2, which represent the doses measured using the TLDs and ionization chamber, respectively. Doses were measured at different locations represented by A, B, C, D, E and M in the tables. The recorded exit dose (C) and ovary dose (M) is a combined scattered dose from both primary beam and from the wall (representative of chest bucky). The fraction of the dose to the ovaries, as a percentage of the ESD at the centre of the X-ray beam, is presented in column 7 of Table 1. Results from Table 1 also show that the dose received by the ovaries is only about 2% less than the entrance surface dose at the level of the ovaries. Two percent is less than the error in the TLD measurement and therefore there is no detectable difference between surface and ovary dose. Thus in Table 2 the percentage ovary dose is calculated using the surface dose at slice 30. More importantly, the surface

Table 2. Doses measured at the surface of the phantom using the ionization chamber, where A is the estimated surface dose (ESD) in the centre of the field, B is the ESD at slice 30, E′ and E are doses with and without the lead apron in place and D are exit doses at slice 27

X-ray settings		Doses (mGy)					B/A × 100
kVp	mAs	A	B	E	E′	D	
70	12	0.241	0.002	0.007	0.006	**	0.73
70	16	0.323	0.002	0.008	0.008	**	0.74
110	12	0.628	0.006	0.02	0.019	0.002	0.94

**Doses less than 1 μGy, the detection limit of the chamber.

dose at slice 27, with and without the lead apron, is essentially the same. The difference in the ratios of B/A in Tables 1 and 2 could be due to the measurement errors associated with the two methods. The minimum detectable dose was 0.05 mGy and 0.001 mGy using TLDs and ionization chamber respectively. The precision error worsens as the detectable limit is approached.

DISCUSSION AND CONCLUSION

Table 1 (column 7) illustrates that the dose received by the ovaries without the lead apron is only approximately 2% of the entrance dose. Assuming an entrance dose of 0.3 mGy, (typical chest exposure of 70 kVp, 4 mAs) only 0.006 mGy will be received by the ovaries.

The second investigation used more realistic mAs and the entrance skin dose recorded is in agreement with those reported in the literature. A survey by Shrimpton *et al.* [5] demonstrated that the average applied potential in a PA chest radiograph was 68.5 kVp ± 18% and the recorded entrance dose per radiograph was 0.23 mGy ± 78%. For the above settings the estimated doses to the ovaries, uterus and testes were below 0.01 mGy. A recent study by Marshall *et al.* [6] investigated the dose associated with different imaging systems (AMBER, film–screen and digital II). They reported that the doses to the testes were not statistically different from background, while the highest measured doses were 0.0023 mGy for film–screen and computer radiography.

There is no significant difference between doses at position E and E′ (Table 2). The doses at position E′ were recorded behind a lead skirt. Therefore no significant reduction in ovary dose will be achieved with the application of a lead skirt since scattered radiation within the phantom is the main source of the organ dose. It is worth noting that dose recorded at slice 30 using the ionization chamber is only about 1% of the entrance surface dose in the field of view. Testes are even lower down and therefore will receive much lower doses than the ovaries.

The absorbed dose is decreased when the kVp is increased and the mAs reduced (Table 1) in the field of view, but the percentage ovary dose is not significantly different. However, the dose is increased either by increasing the kVp and keeping mAs constant or increasing mAs and keeping kVp constant (Table 2).

From the above discussion it could be concluded that if the field of view is collimated to the film then there is negligible radiation protection benefit in using additional lead shielding except to reassure the patient. This is in agreement with the ICRP's gonad shielding policy, which states that 'if the gonads are beyond 5 cm the gain obtained in shielding is negligible' [7].

References

1. National Radiological Protection Board. Patient dose reduction in Diagnostic Radiology. HMSO, London, Documents of the NRPB 1990; 1(3): 3–11.
2. International Commission on Radiological Protection, 1990. Recommendation of the International Commission on Radiological Protection. Oxford: Pergamon Press, 1991: ICRP Publication 60. *Ann ICRP*; **21**(1–3).
3. International Commission on Radiological Protection. Report of the task group on reference man. Oxford: Pergamon Press, 1975: ICRP Publication 27.
4. Huda W, Sandison GA. Estimation of mean organ doses in diagnostic radiology from Rando Phantom measurements. *Health Phys 1984;* **47:** 463–7.
5. Shrimpton PC, Wall BF, Jones DG, *et al.* Doses to patients from routine diagnostic x-ray examination in England. *Br J Radiol* 1986; **59:** 749–58.
6. Marshall NW, Faulkner K, Busch HP, *et al.* An investigation into the radiation dose associated with different imaging systems for chest radiology. *Br J Radiol* 1994; **67:** 353–9.
7. International Commission on Radiological Protection. Protection of the Patient in Diagnostic Radiology. Oxford: Pergamon Press, 1982: ICRP Publication 34. *Ann ICRP* 9, No 2/3.