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Radiation protection of the ovaries in young scoliosis patients

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Abstract Concerns in clinical practice arose over the amount of ovarian irradiation received from X-ray examinations in females with scoliosis. This study was instigated to assess the adequacy of ovarian protection in this young and genetically vulnerable group of patients. A total of 283 plain films in 20 patients with scoliosis were reviewed. If the area immediately adjacent to the medial wall of the acetabulum was clearly seen, then this was taken as indicative of ovarian irradiation. In a separate study, the radiation dose in the centre of the X-ray field on the surface of a tissue-equivalent anthropomorphic phantom was measured using thermoluminescent dosimeters. Standard conditions for scoliosis X-ray examination were used. The average age of patients was 21.5 years. The mean number of single X-ray exposures per patient was 14.1 over a mean of 44 months. The mean measured en-

trance dose to the skin in the 20 patients was 0.08 mGy (equivalent dose = 0.08 mSv). The mean percentage of examinations without lead protection was 18% per patient (range 0–40%). This would have resulted in a mean equivalent dose to the surface of the abdomen of 0.1 mSv per year per patient from the unprotected examinations. The maximum dose received in 1 year was 0.6 mSv. The maximum dose to the unprotected ovary was estimated to be 0.05 mSv from a single examination. The mean total cumulative ovarian dose was calculated as 180 μ Sv per patient (range 45–355 μ Sv) over the time period studied. The findings of this study indicate that ovarian protection should be improved. Reasons for this and suggestions for improvement are discussed.

Key words Scoliosis · Radiation dose · Ovary

Introduction

Adolescent idiopathic scoliosis is a disorder that predominantly affects females. Direct irradiation of the ovaries in scoliosis patients can potentially occur when X-ray examination of the spine is performed in order to diagnose and monitor progression of the condition. As longevity and reproductive capability are not affected by scoliosis, gonadal irradiation is an important issue. We therefore examined the radiographs of 20 patients who attended the spinal scoliosis clinic at our institution, looking particularly for evidence of direct ovarian irradiation.

Materials and method

Twenty female patients who had been followed up for more than 6 months were randomly selected from our scoliosis clinic database. The postero-anterior (PA) and lateral plain films of these selected patients were examined. When the area immediately adjacent to the medial wall of the acetabulum was clearly seen (see Fig. 1), this was taken as indicative of direct ovarian irradiation.

In a separate study, TLDs (thermoluminescent dosimeters) were used to measure the absorbed dose in the centre of the X-ray field on the surface of a tissue-equivalent anthropomorphic phantom (ART, Gothic Crellon, UK) without lead protection. TLDs were also used to measure the absorbed dose from scattered radiation at the approximate location of the ovaries in protected and un-

Fig.1 Lower section of long anterior-posterior scoliosis radiograph demonstrating lead shield that has slipped down below the hip joints

protected examinations. Measurements with TLDs were carried out under the same conditions (Voltage, current, distance and orientation, i.e. PA) as used for scoliosis examinations at our institution (see Discussion). In order to improve the accuracy of the TLD measurements, each dosimeter was exposed to 50 identical exposures. The doses quoted are the results for a single exposure.

Results

The 20 patients were all female, with an average age of 21.5 years (range 11–43 years). The average number of X-rays per patient was 14.1 (range 9–24) over a mean period of 44 months (range 8–150 months). In the group as a whole there were 283 films. According to our criteria, 51 of these had inadequate protection of the gonads. The average percentage of examinations without lead protection was 18% per patient (range 0–40%). The average number of films in which direct ovarian irradiation was judged to have occurred was therefore 2.6 per patient.

An explanation of terms of radiation dosage is necessary at this point. The entrance dose measured with the TLDs in the second part of the study is the absorbed dose of radiation (mGy). The equivalent dose (mSv) depends on the nature of the radiation used, (in this case X-rays), and is the absorbed dose multiplied by a quality factor. This factor is 1 for X-rays, and thus although the units for absorbed dose and equivalent dose are different the values are the same.

The mean measured entrance dose to the skin from the second part of the study was 0.08 mGy for each exposure (equivalent dose 0.08 mSv). This value is well below the reference dose level specified by the National Radiological Protection Board [3] for a standard lumbar spine examination. This is due to the technique employed for a scoliosis X-ray series in our institution (e.g. no grid, long focal distance; see Discussion).

Table 1 Results of the radiographic examinations of 20 patients

Patient no.	Age (years)	Total no. of films	Films without protection	Time period (months)	Total skin dose without protection (mSv)	Yearly skin dose without protection (mSv)
1	30	14	1	74	0.08	0.01
2	11	16	2	56	0.16	0.03
3	18	6	2	20	0.16	0.09
4	27	24	4	150	0.32	0.02
5	15	18	5	8	0.4	0.6
6	43	10	4	19	0.32	0.2
7	26	20	2	40	0.16	0.04
8	15	10	3	20	0.24	0.14
9	19	9	0	36	0	0
10	20	15	3	22	0.24	0.13
11	16	14	0	36	0	0
12	29	16	3	19	0.24	0.15
13	21	12	2	20	0.16	0.09
14	25	13	2	54	0.16	0.03
15	17	18	1	74	0.08	0.01
16	16	12	3	23	0.24	0.13
17	20	8	2	39	0.16	0.05
18	19	12	4	148	0.32	0.03
19	15	26	5	9	0.4	0.53
20	27	10	3	21	0.24	0.14
Mean	21.5	14.2	2.6	44	0.23	0.11

Table 2 Calculated cumulative total ovarian dose from protected and unprotected examinations

Patient no.	No. of films without protection	No. of films with protection	Cumul. ovarian dose unprotected (μSv)	Cumul. ovarian dose protected (μSv)	Total ovarian dose received (μSv)
1	1	13	50	55	115
2	2	14	100	70	170
3	2	4	100	20	120
4	4	20	200	100	300
5	5	13	250	55	315
6	4	6	200	30	230
7	2	18	100	90	190
8	3	7	150	35	185
9	0	9	–	45	45
10	3	12	150	60	210
11	0	14	–	70	70
12	3	13	150	65	115
13	2	10	100	50	150
14	2	11	100	55	155
15	1	17	50	85	135
16	3	9	150	45	195
17	2	6	100	30	130
18	4	8	200	40	240
19	5	21	250	105	255
20	3	7	150	35	185
Mean			142	58	180.5

If this average skin dose of 0.08 mGy per film is assumed, the average dose to the skin in the unprotected examinations can be calculated as 0.2 mSv per patient during the time period considered. After introducing the time factor to allow for examination frequency and a quality factor to convert from measured absorbed dose to an equivalent dose for X-rays, this equates to a dose to the skin surface of 0.1 mSv per year per patient (range 0–0.6 mSv per year per patient, see Table 1) when the ovaries were unprotected.

The mean absorbed dose from scattered radiation per X-ray examination, measured at the location of the ovaries in the phantom, was 4.8 μSv . This represents the dose to the ovaries outside the field of view and will be similar to the dose received by the protected ovaries. The maximum dose to the unprotected ovaries within the field of view was estimated from TLD measurements as 0.05 mSv, assuming that the whole of the ovarian structure was exposed. Using these values to calculate the total dose of ovarian irradiation received by each patient in each unprotected and protected X-ray examination, the mean total cumulative ovarian dose is 180 μSv per patient (range 45–355 μSv) over the time period studied (see Table 2).

Discussion

The Ionising Radiation Regulations [4] require that the dose limit to the abdomen of a woman of reproductive ca-

capacity, who is employed as a radiation worker, does not exceed 50 mSv per year (averaged throughout the abdomen). This implies an acceptable level of risk resulting from gonadal irradiation in workers. The mean of 0.1 mSv per year at the surface of the abdomen in our patients who had unprotected examinations appears satisfactory.

The hazards of gonadal irradiation include teratogenesis (if the ovum is fertilised), genetic disorders in the patient's offspring (e.g. increased risk of childhood malignancy) along with intangible effects on the total population genetic burden [5].

In girls the gonads are more difficult to protect than in boys. CT scans of women have shown the ovaries to be situated adjacent to the iliac bones, approximately on a line bisecting the antero-posterior diameter of the pelvis (Ledley [2]). This position equates with the criteria for gonadal irradiation described in this study. However, it must be remembered that the ovaries are mobile structures and this landmark is a "best guess" only.

The concepts of "maximum permissible dose" and "dose limits" are not strictly applicable in the case of patients undergoing diagnostic examination or therapy with ionizing radiation (NRPB [3]). There are no mandatory limits for patient doses, but there is a responsibility to ensure that the exposure is justified and that the protection is optimised (ICRP, p 43 [5]). There are no mandatory limits for doses to specific organs. Reference skin doses have been defined for common X-ray examinations, but not for scoliosis examinations [4].

The mean dose of 0.1 mSv per year to the surface of the unprotected abdomen in these patients, with all patients having values significantly less than the 50 mSv per year recommended in the Ionising Radiation Regulations [4], is encouraging. The mean total cumulative ovarian dose of 180 μ Sv per patient has unknown significance for the reasons suggested above on dose limits for specific organs. There are thus a number of uncertainties when considering the cumulative effects of gonadal irradiation in the long term; even so, it should be possible to improve on the figure in our study of 18% of X-ray examinations having inadequate ovarian protection.

We take the following measures in our hospital to prevent gonadal irradiation: avoidance of examinations in pregnant women (using the 28-day rule), the use of posterior-anterior films, low-dose fast exposure films, the use of an air gap and 2.3 m focal distance between source of beam and the patient, the wearing of a lead apron (5 mm thick) to protect the ovaries, and coned down views of the affected area (lead protection systems used correctly have been shown to be effective in significantly reducing ovarian irradiation [1]).

Requirements for a surgeon in the interpretation of plain radiographs in a standing position in patients with scoliosis include: pelvic obliquity, Risser's sign, a visible L5/S1 junction and a view of the triradiate cartilage for the assessment of bone age.

The problems that arise for the radiographer are:

1. Radiographers find it difficult to show the sacroiliac joints on X-ray films (which they consider important for a scoliosis series), whilst protecting the ovaries.
 2. Patients find it difficult to wear the lead apron, and once on, the belt often slips (Fig. 1).
 3. Coned down views are often difficult in patients with severe scoliosis.
 4. In order to reveal the whole spine, the first scoliosis series is often taken without lead protection (to show the entire lumbo-sacral area).
- These problems have recently been overcome by:
1. Requesting the radiographers to ignore the sacroiliac joints and show only down as far as the L5/S1 junction, making gonadal protection easier
 2. The use of a free-standing, height-adjustable lead stand in front of the patient instead of lead aprons
 3. Avoiding coning in patients with severe scoliosis
 4. Lead protection of the ovaries on the first film series (except in younger patients, where views of the triradiate cartilage are required)

Conclusions

The introduction of the simple measures suggested above, along with increased awareness of the problems by radiographers and surgeons alike, has resulted in improvements in ovarian protection at our institution. We feel that this is important in such a young but genetically vulnerable group of patients.

We recommend a regular audit of radiation protection in scoliosis to ensure appropriate gonadal protection and adoption of the suggested preventative measures.

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