

COMPARISON OF SURFACE RADIATION DOSE TO THE GONADS BY RADIOGRAPHIC EXAMINATION OF THE LUMBAR SPINE USING COMPUTED RADIOGRAPHY AND DIRECT DIGITAL RADIOGRAPHY

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ABSTRACT

Introduction: Lumbar spine radiography is an inexpensive and quick imaging technique which is often used for the evaluation of bony structures and initial screening examination for suspected fractures, congenital spinal defects, malalignment, and degenerative changes of the spine. During lumbar spine radiography, gonads are also irradiated. As gonads are radiosensitive organs, biological damage produced by radiation is closely related to the amount of energy absorbed. Surface radiation dose (SRD) is a measurement of dose received by the skin of the patient where the X-ray beam passes through the patient.

Objectives: The objectives are aimed to study the comparison of SRD to the gonads by radiographic examination of the lumbar spine using computed radiography (CR) and direct digital radiography (DR) and to evaluate dose differences according to gender.

Methods: A total of 120 subjects with an equal number of males and females referred for lumbar spine anteroposterior (AP) and lateral was included in the study. Sixty patients had undergone X-ray in CR X-ray unit and 60 in DR X-ray unit. SRD to gonads from a radiographic examination of the lumbar spine was measured in CR and DR using Mult-O-Meter, and obtained value of SRD was in μGy . Statistical analysis was performed using Statistical Package for the Social Sciences. Data were represented as a median and interquartile range. Mann-Whitney U-test was used for the comparison of SRD to gonads. Two-way analysis of variance (ANOVA) test was used to find out the statistically significant difference in SRD to the gonads according to gender from radiography of lumbar spine taken using CR and direct DR.

Results: There was a statistically significant difference in SRD to gonads from radiography of lumbar spine AP and lateral taken using CR and direct DR ($p < 0.001$). There was no statistically significant difference in SRD to the gonads in males and females from radiography of lumbar spine AP ($p = 0.577$) and lateral ($p = 0.164$) taken using CR and direct DR.

Conclusion: It was found that SRD to gonads from lumbar spine AP was 54% lower in direct DR and SRD to gonads from lumbar spine lateral was 68% lower in direct DR than CR.

Keywords: Surface radiation dose, Computed radiography, Direct digital radiography, Lumbar spine.

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INTRODUCTION

Radiography is often the first line of choice in diagnosis due to its speed, availability, and lower costs compared to other imaging modalities. The lumbar spine radiography is an inexpensive and quick imaging technique which is often used for the evaluation of bony structures and initial screening examination for suspected fractures, congenital spinal defects, malalignment, and degenerative changes of the spine. At present, radiography of lumbar spine is frequently taken in patients with low back pain to evaluate degenerative changes of the spine such as osteoporosis [1,2]. Radiographic examination of the lumbar spine commonly includes anteroposterior (AP) and lateral view. With the increased advantage of direct digital imaging systems for medical diagnostics, digital imaging is necessary in the health care [3].

Radiographic examinations are associated with both benefits and risk. Radiotherapy is one of the effective methods of cancer therapy [4]. Gonads are radiosensitive organs. Radiation can impair oocyte function, leading to impaired or non-fertility. Radiation dose required to have these effect decreases with age due to falling total oocyte numbers. Similarly, radiation exposure to the testes can result in temporary or permanent azoospermia. Permanent sterility occurs after gonads have received 2.5-3.5 Gy [5].

Surface radiation dose (SRD) is a measurement of dose received by the skin of the patient, where the X-ray beam passes through the patient. SRD can be measured using thermoluminescent dosimeter (TLD), pocket dosimeter, or Mult-O-Meter [6].

In this study, SRD to gonads was measured in computed radiography (CR) and direct digital radiography (DR) during radiographic examination of lumbar spine using Mult-O-Meter, and obtained value of SRD was in μGy .

METHODS

The study was a cross-sectional study, conducted in the Radio Diagnosis and Imaging Department at Kasturba Hospital, Manipal, during April 2016 to March 2017. The sample size was obtained using the formula for the estimation of mean with 5% level of significance. About 120 subjects with equal males and females referred for AP, and lateral X-ray of the lumbar spine was included in the study. The study approval was acquired by the Institutional Research Committee, School of Allied Health Sciences, and Institutional Ethics Committee, Kasturba Hospital, Manipal. Informed consents were obtained from all the study participants. Subjects with age ranging from 18 to 50 years and body mass index (BMI): 18.5-24.9 were included in the study. Individuals with a history of trauma were excluded from this study.

Sixty subjects had undergone X-ray in CR-Fujifilm, and 60 subjects had undergone X-ray in DR-Philips Medical Systems digital diagnostic TH. Exposure factors set in direct DR unit was based on automatic exposure control (AEC), whereas manual factors were set in the CR unit ranging from 65 to 75 kVp and 100-125 mAs. For measuring the SRD to gonads from radiographic examination of the lumbar spine in AP and lateral view, a Mult-O-Meter was placed on the surface of the patient close to the pelvic region. Mult-O-Meter consists of a ionization chamber and small external detector that measures kVp, dose, dose rate, and time simultaneously. The obtained value of SRD was in μGy . The effective dose can be calculated from the SRD using the following formula:

$$E = k \times \text{SRD}$$

- E=Effective dose
- k=Conversion factor
- SRD=Surface radiation dose

As per the National Radiological Protection Board (NRPB)-SR262 Monte Carlo data [7], conversion factors used were 0.109 and 0.018 for lumbar spine AP and lumbar spine lateral, respectively.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences version 22.0. As the SRD to the gonads from radiographic examination of the lumbar spine in AP and lateral view using CR and direct DR was not normally distributed, data were summarized as a median and interquartile range.

Mann-Whitney U-test was used for the comparison of SRD to gonads. Two-way ANOVA test was used to find out the statistically significant difference in SRD to gonads according to gender from radiography of lumbar spine taken using CR and direct DR. Statistical significance was considered at $p < 0.05$.

RESULTS

A total of 120 subjects with an equal number of males and females referred for lumbar spine AP and lateral was included in the study with age ranging from 18 to 50 years and BMI: 18.5-24.9. From the 120 subjects, 60 subjects had undergone X-ray in CR X-ray unit, and 60 subjects had undergone X-ray in DR X-ray unit.

Median SRD and interquartile range to gonads from lumbar spine AP in CR and direct DR were evaluated. Fig. 1 shows that median SRD to gonads from lumbar spine AP in CR was found to be 271.25 μGy with lower quartile (Q1) of 242.7 μGy and upper quartile of (Q3) 321.65 μGy . In DR, the median SRD to gonads was found to be 77.27 μGy with lower quartile (Q1) of 42.51 μGy and upper quartile (Q3) of 112.75 μGy .

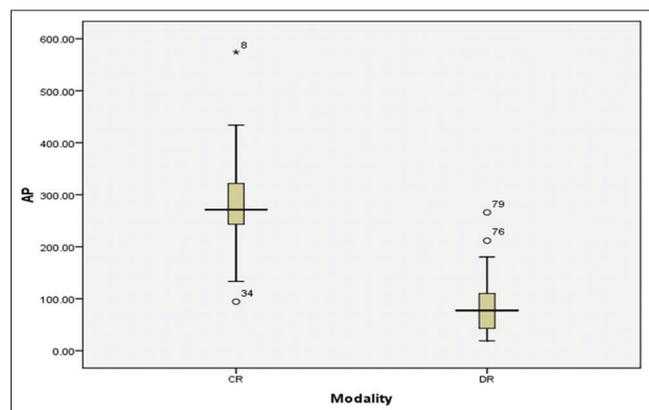


Fig. 1: Box plots representing median surface radiation dose for lumbar spine anteroposterior for computed radiography and direct digital radiography

Mann-Whitney U-test was performed to compare median SRD for lumbar spine AP using CR and direct DR. The test statistic for a Mann-Whitney U-test was 82, with a $p < 0.001$. Therefore, the results showed that there is a significant difference in median SRD to gonads from lumbar spine AP taken using CR and direct DR.

Median SRD and interquartile range to gonads from of lumbar spine lateral in CR and direct DR were evaluated. Fig. 2 shows that median SRD to gonads from lumbar spine lateral in CR was found to be 432.45 μGy with lower quartile (Q1) of 310.20 μGy and upper quartile (Q3) of 660.45 μGy . In DR, the median SRD to gonad was found to be 87.98 μGy with lower quartile (Q1) of 62.15 μGy and upper quartile (Q3) of 126.19 μGy .

Mann-Whitney U-test was performed to compare median SRD between two groups, namely, lumbar spine lateral taken using CR and direct DR. The test statistic for a Mann-Whitney U-test is 71, with a $p < 0.001$. The results showed a significant difference in median SRD to gonads from lumbar spine lateral taken using CR and direct DR.

Effective dose was calculated from SRD using a conversion factor. Table 1 shows that mean effective dose to gonads from lumbar spine AP and lateral in CR and DR.

The mean SRD to gonads in males and females from a radiographic examination of lumbar spine AP with CR and direct DR was also evaluated. SRD to gonads from lumbar spine AP in males was found to be $282.29 \pm 81.92 \mu\text{Gy}$ in CR and 75.24 ± 43.40 in DR. The mean SRD to gonads from lumbar spine AP in females was found to be $281.97 \mu\text{Gy} \pm 83.17$ in CR and $91.05 \mu\text{Gy} \pm 58.11$ in DR as shown in Fig. 3.

Statistical analysis was performed using two-way ANOVA test. The test revealed that there was a significant difference between CR and direct DR ($p < 0.001$), but there is no significant difference in gender ($p = 0.577$).

Mean SRD to gonads in males and females from radiographic examination of lumbar spine lateral with CR and direct DR was also evaluated. Mean SRD to gonads from lumbar spine lateral in males was

Table 1: Conversion factor and mean effective dose to gonads from lumbar spine AP and lateral taken using CR and DR

Projections	Conversion factor	Effective dose in CR (μSv)	Effective dose in DR (μSv)
Lumbar spine AP	0.109	30.73 ± 8.94	9.06 ± 5.60
Lumbar spine lateral	0.018	8.38 ± 3.35	1.83 ± 4.08

CR: Computed radiography, DR: Digital radiography, AP: Anteroposterior

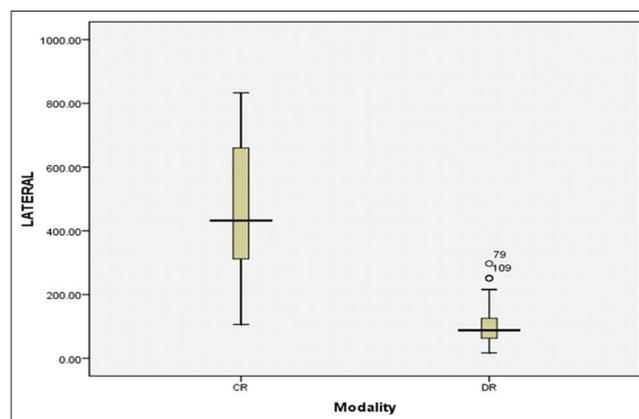


Fig. 2: Box plots representing median surface radiation dose for lumbar spine lateral for computed radiography and direct digital radiography

Table 2: Mean SRD and percentage differences between the SRD from radiography of lumbar spine using CR and DDR

Studies	Radiography of lumbar spine	Mean SRD in CR	Mean SRD in DR	DDR versus CR
Compagnone <i>et al.</i>	Lumbar spine AP	2.54 mGy	1.16 mGy	-54%
	Lumbar spine lateral	5.39 mGy	1.72 mGy	-68%
Panicker <i>et al.</i>	Lumbar spine lateral	19.15 mSv	11.01 mSv	-42%
Present study	Lumbar spine AP	282.13 μ Gy	83.14 μ Gy	-70%
	Lumbar spine lateral	465.56 μ Gy	102.11 μ Gy	-78%

SRD: Surface radiation dose, CR: Computed radiography, DR: Digital radiography, DDR: Direct digital radiography, AP: Anteroposterior

Table 3: Mean effective dose from radiography of lumbar spine in the present work compared with various data established reported in literature

Studies	Radiography of lumbar spine	Mean effective dose (mSv)
Gyekye <i>et al.</i>	AP	10.4
	Lateral	8.6
Suliman <i>et al.</i>	AP	34.9
	Lateral	15.3
Present study	AP	19.90
	Lateral	5.10

AP: Anteroposterior

found to be 506.69 μ Gy \pm 196.06 in CR and 96.02 μ Gy \pm 56.33 in DR. Mean SRD to gonads from lumbar spine lateral in females was found to be 424.43 μ Gy \pm 187.03 281 in CR and 108.19 μ Gy \pm 58.58 in DR as shown in Fig. 4.

Statistical analysis was performed using two-way ANOVA test. The test revealed that there was a significant difference between CR and direct DR (p<0.001), but there is no significant difference in gender (p=0.164).

DISCUSSION

The present study compares the SRD received by the gonads during the radiographic examination of the lumbar spine in CR and direct DR and evaluates dose differences according to gender.

In a study conducted by Compagnone *et al.*, SRD was calculated by the mathematical model using outputs measured by ionization chamber [8]. However, in the present study, the SRD to gonads was measured using Mult-O-Meter, and obtained value of SRD was in μ Gy. There are various methods to estimate SRD. In a pilot study done by Panicker *et al.*, SRD to the patient undergoing lumbar spine lateral radiography in conventional X-ray unit and the digital X-ray unit was measured using TLD, and obtained value of electrostatic discharge (ESD) was in mSv [9].

In this present study, it was found that SRD to gonads from lumbar spine AP was 70% lower in DR than CR, whereas SRD to gonads from lumbar spine lateral was 78% lower in DR than CR. However, the present study compares only CR and DR, a study performed by Compagnone *et al.* compares CR, DR, and film-screen systems and also calculated the effective dose. The effective dose in dual delayed-release (DDR) was 29% lower compared to screen film radiography and 43% lower in DDR compared to CR. Another study done by Panicker *et al.* found that ESD from radiography of lumbar spine lateral in DR was 42% lower than CR X-ray unit (Table 2).

The reason for a lower SRD to gonads in direct DR might be due to various factors such as the greater dynamic range, higher efficiency in signal conversion, and usage of higher kVp and the lower mAs within the diagnostic range that adequately exposes the image receptor to give a diagnostic quality image. Another possible reason for lower SRD to gonads in DR could be due to the use of AEC during lumbar spine radiography, whereas in CR, exposure factors are set manually by radiographer.

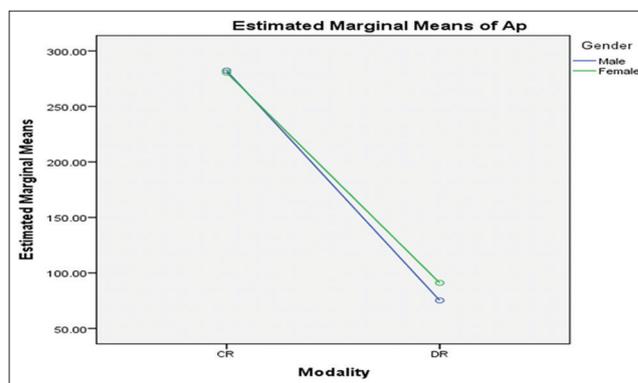


Fig. 3: Profile plots representing mean surface radiation dose for males and females in lumbar spine anteroposterior

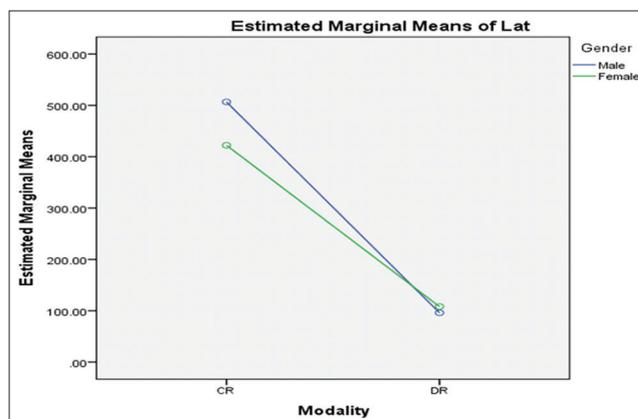


Fig. 4: Profile plots representing mean surface radiation dose for males and females in lumbar spine lateral

The present study also estimated the mean effective dose during lumbar spine radiography in CR and DR using NRPB conversion factors. The mean effective dose to gonads in CR and DR from lumbar spine radiography was found to be 19.56 μ Sv and 5.45 μ Sv, respectively. A study conducted by Compagnone *et al.* showed an effective dose of 0.476 mSv and 0.179 mSv in CR and DR, respectively, for lumbar spine radiography [8]. They used a similar method to calculate the effective dose from SRD using NRPB conversion factors. It was found effective dose of lumbar spine AP was about twice that of lumbar spine lateral which is similar to the present study (Table 3).

A study conducted by Toosi *et al.* reported that dose to gonads from radiography of lumbar spine using CR for the females was found much higher than for males [10]. The present study also evaluated the mean SRD to gonads in both the genders. It was found that there is no statistically significant difference in SRD to gonads according to gender. However, mean SRD to gonads from radiographic examination of the lumbar spine in AP and lateral using DR was lower than CR in both males and females.

Limitations and recommendations

There are limited studies reported to evaluate SRD during an X-ray of the lumbar spine in CR and DR [8,11,12]. As a result, SRD and effective dose to the gonads in the present work could not be compared with state and national diagnostic reference levels. Therefore, further studies can be conducted to set up the state and national diagnostic reference levels of SRD and effective dose.

CONCLUSION

The mean SRD to gonads from lumbar spine AP was found to be 282.13 μ Gy in CR and 83.14 μ Gy in direct DR. The mean SRD to gonads from lumbar spine lateral was found to be 465.56 μ Gy in CR and 102.11 μ Gy in direct DR.

It was found that SRD to gonads from lumbar spine AP was 54% lower in direct DR and SRD to gonads from lumbar spine lateral was 68% lower in direct DR than CR.

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