Scientific Paper

# Evaluation of effective dose and entrance skin dose in digital radiology

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## Abstract

Background: Ionizing radiation has an indispensable role in diagnostic radiology and clinical treatments. Apparently, medical exposure in diagnostic radiology pertains to be the preeminent man-made source of radiation.

Objective: The aim of the present scientific study is to calculate the Entrance Surface Dose (ESD) and Effective Dose (ED) in digital radiography in Mazandaran province.

Materials and methods: The study was performed on 3600 patients in digital X-ray rooms 15 hospitals and the required data were collected from two age groups (10>15 years and adults) in each projection. Based on the results of this study, ESD and ED were calculated for skull (PA), skull (lateral), cervical spine (AP), cervical spine (lateral), chest (PA), chest (lateral), abdomen (AP), lumbar spine (AP), lumbar spine (lateral), pelvis (AP), thoracic spine (AP) and thoracic spine (lateral) examinations. It was calculated using PCXMC software (version 2.0).

Results: In this study, mean ESDs for the 10-15 year group varied from 0.97±0.21 mGy to 3.62±1.38 mGy for chest (PA) and lumbar spine (lateral), respectively. For the adult group varied from 1.05±0.31 to 3.85±1.44 for cervical spine (AP) and lumbar spine (lateral), respectively. And also ED value was from in the range of 10.40 µSv to 378.46 µSv for skull (PA) 10-15 year group and abdomen adults, respectively

Conclusion: This survey revealed a significant variation in the radiation dose of digital radiology examinations among hospitals in Mazandaran province. Application of a dose reference level (DRL) could be an optimization procedure for reducing the patient's dose in Mazandaran province.

**Key words**: diagnostic radiology; patient dose; dosimetry; dose reference level; entrance surface dose; effective dose.

## Introduction

Humans have always been exposed to two types of radiation, the first of which involves environmental radiation, and the second artificial radiation [1]. Since the discovery of X-rays in 1895, the process of diagnosing the disease has greatly improved and today, X-ray examinations are widely used in all medical centers around the world, but despite its many advantages in treatment and patient care can pose risks to patients if they do not comply with the principles of protection [2].

As more X-ray machines are developed and more complex examinations are performed, the radiation dose of patients has also increased. Most people are exposed to X-rays from artificial human sources, due to the inevitability of X-rays and its pervasiveness among the people [3]. Radiological procedures, such as simple films or digital equipment, make up 48% of all diagnostic radiology examinations [4].

The diagnostic radiographic examination of patients, which has the largest contribution to the use of ionizing radiation in medicine, has been the focus of research on dose reduction techniques in diagnostic radiology and has always been a primary focus of research in the field of protection and safety, especially for patients [5].

Optimization and dose reduction should be performed without reducing or losing the necessary diagnostic information. Optimization of protection in diagnostic radiology does not merely mean a reduction of the patient's dose, and more importantly, the obtained image should contain appropriate diagnostic information [6].

Entrance Skin Dose (ESD) is an important parameter in evaluating the dose received by a patient in radiography. The European Union has identified this amount in the hope of optimizing the patient's dose as a diagnostic reference. Effective Dose (ED) is the best value for assessing radiation risks for patients. The most important advantage of using ED is that this parameter measures the absorbed doses and the relative radiation of the irradiated organs in patients, and better assess the patient risk [7,8].

In this study, ED and ESD quantities, which are common quantities for routine dose monitoring in conventional radiographic examinations, were used in routine diagnostic radiology examinations [9,10].

All the x-ray machine used in this study were digital. With the increasing and widespread use of digital radiography and the emergence of digital systems, demands for radiology imaging have grown [13]. Additionally also the transition of analog to digital has increased the patient's dose due to a significant increase in the wide dynamic range. A wide dynamic range makes it possible to elevate the radiation conditions without any detrimental effects on the quality of the images. However, insufficient training of the technicians has aroused some problems in this field [14].

The purpose of this study is to measure ESD and ED from 15 radiology centers of public hospitals in Mazandaran province (Iran) for 12 common digital radiographic examinations including skull (PA), skull (lateral), cervical spine (AP), cervical spine (lateral), thoracic (AP), thoracic (lateral), chest spine (PA), chest spine (lateral), lumbar spine (AP), lumbar spine (lateral), abdomen (AP), and pelvis (AP).To the beast of our knowledge, this is the first study done on the calculation of the ED and ESD in digital radiology in Mazandaran province.

## Materials and methods

### Data collection method

In this study, 15 radiography rooms in 15 hospitals in Mazandaran province (Iran) were selected. The information of 12 common digital radiography examinations including skull (PA), skull (lateral), cervical spine (AP), cervical spine (lateral), chest (PA), chest (lateral), abdomen (AP), lumbar spine (AP), lumbar spine (lateral), pelvis (AP), thoracic spine (AP) and thoracic spine (lateral) examinations which were performed in each radiography room was recorded for 10 to 15 years old patients and adult patients. The total number of patients studied in this study was 1800 for the age group of 10-15 years and 1800 for the adults. First, information about radiation parameters (kVp, mAs), geometric parameters including Focus to Skin Distance (FSD), and Focus to Detector Distance (FDD) used in the radiographic examination was recorded. On the other hand, there was no significant difference in body weight and body mass index of patients referring to different centers, which is due to the selection of patients for the 10 to 15 years group with the mean weight

between 40 to 60 kg and the age group adult 60 to 80 kg. Conspicuously, the distribution of the experimental groups was categorized according to age, sex, weight and height, and the number of patients who participated in each age group, and the information are presented in **Table 1**. Distinctly, the number of patients who underwent each X-ray examination is presented in **Table 2**, according to their gender. In **Table 3** the FFD and exposure settings (X-ray tube voltage (kVp), tube current-time product (mAs), and radiation field size) associated with each X-ray examination are presented.

## Measurements of the X-Ray tube output

For measurement of outputs, a dosimetry kit includes a flat solid-state dosimeter were used (Barracuda X-ray Analyzer, RTI Electronics, Sweden) was used. Calibration of the detector was performed in a Secondary Standard Dosimetry Laboratory (SSDL). This dosimeter was calibrated to measure air kerma in the energy range of 40 to 150 kVp to measure mAs, time, dose rate, (Half Value Layer) HVL, and kVp parameters. After connecting to the electrometer, a low-scattering material (a wide cardboard plate) was placed on the central axis of the radiation beam at a distance of 100 cm from the focal points, of the X-rays. Then, the size of the radiation field on the detector was set as a 15×15 cm field to minimize the effect of the scattered radiation on the detector. In this case, a constant mA of 10 mAs and tube voltages of 40-110 kVp were set and the dose was recorded by the dosimeter [11].

**Table 1. Number of patients in age groups and patient body characteristics (age, height, and weight) of each sex.**

| Age Group | Weight (kg) | | Height (cm) | | Female | Male | Total |
|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | | | |
| 10-15 years | 49.70 | 29.5-70 | 152.50 | 134-177 | 983 | 817 | 1800 |
| Adult | 76.60 | 58-83 | 171.20 | 145-192 | 803 | 997 | 1800 |
| Total | | | | | 1786 | 1814 | 3600 |

**Table 2. Sex distribution of the studied groups in each examination**

| X-ray examination | Female | Male | Total |
|---|---|---|---|
| Skull (PA) Skull (lateral) | 90 | 85 | 175 |
| Cervical spine (AP) Cervical spine (lateral) | 154 | 113 | 267 |
| Chest (PA) | 247 | 308 | 555 |
| Chest (lateral) | 165 | 153 | 318 |
| Thoracic spine (AP) Thoracic spine (lateral) | 251 | 244 | 495 |
| Lumbar spine (AP) Lumbar spine (lateral ) | 283 | 290 | 573 |
| Pelvis (AP) | 246 | 304 | 550 |
| Abdomen (AP) | 350 | 317 | 667 |
| Total | 1786 | 1814 | 3600 |

**Table 3. Summary of the patient attributes and applied exposure parameters, including mean (minimum-maximum) values**

| X-ray examination | Age | kVp | mAs | FFD (cm) |
|---|---|---|---|---|
| Skull (PA) | 10 - 15 year<br>Adult | 61.50 (57-67)<br>67 (60-75) | 24.50 (20-32)<br>26.84 (12-27) | 90-100 |
| Skull (Lateral) | 10 - 15 year<br>Adult | 62.63 (59-65)<br>65.61 (63-76) | 21.58 (20-32)<br>26.21 (12-32) | 90-100 |
| Cervical spine (AP) | 10 - 15 year<br>Adult | 61.12 (56-64)<br>65.30 (52-77) | 22.11(20-32)<br>26.60 (10-32) | 90-100 |
| Cervical spine (Lateral) | 10 - 15 year<br>Adult | 62 (53-70)<br>64.50 (62-76) | 20.46 (19-31)<br>22.49 (10-32) | 90-100 |
| Chest (PA) | 10 -15 year<br>Adult | 71.22 (62-78)<br>81.31 (66-93) | 8.50 (10-19)<br>9.51 (10-21) | 120-180 |
| Chest (Lateral) | 10 - 15 year<br>Adult | 77.73 (68-82)<br>86.41 (70-95) | 14.22 (14-24)<br>18.27 (10-32) | 120-180 |
| Thoracic spine (AP) | 10 -15 year<br>Adult | 67.56 (61-78)<br>75.30 (64-88) | 22.42 (15-29)<br>25.50 (12-40) | 90-100 |
| Thoracic spine (Lateral) | 10 - 15 year<br>Adult | 74.81 (66-87)<br>79 (69-89) | 25.40 (12-32)<br>30.50 (18-51) | 90-100 |
| Lumbar spine (AP) | 10 - 15 year<br>Adult | 68 (67-73)<br>74.66 (68-83) | 28.23 (24-34)<br>32.77 (26-40) | 90-100 |
| Lumbar spine (Lateral) | 10 - 15 year<br>Adult | 77.22 (71-80)<br>83.43 (77-90) | 37.84 (27-39)<br>41 (27-29) | 90-100 |
| Abdomen (AP) | 10 - 15 year<br>Adult | 68.20 (15-38)<br>75 (65-90) | 24.10 (15-38)<br>27.70 (17-40) | 90-100 |
| Pelvis (AP) | 10 - 15 year<br>Adult | 66.88 (64-69)<br>72.61 (68-85) | 22.11 (17-39)<br>25 (18-42) | 90-100 |

## ESAK calculation

Finally, the Entrance Surface Air Kerma (ESAK) value was calculated from the kerma value obtained from the Back Scatter Factor (BSF). The value of BSF, from by the European Commission report is between 1.2 and 1.4. This coefficient varied from 1.28 to 1.37 in the present study [10,11].

$$ESAK = D_{air} \times BSF \times (FDD/FSD)^2 \qquad \text{Eq. 1}$$

$D_{air}$ is the reading value of the dosimeter in (mGy), BSF is backscatter factor which was ranging 1.28 to 1.37 in this study, the distance of the focal spot to a detector is referred to as FDD, and FSD is the distance of x-ray focal spot to the patient body [10,12].

## Entrance Skin Dose (ESD) calculation

For the calculation of ESD, ESAK was multiplied to a mass energy absorption coefficient which is equal to 1.06 for tissue and air ( this ratio is approximately 1.06 in digital radiology in 110kvp, with ±1% error) [10].

$$ESD = ESAK \cdot 1.06 \qquad \text{Eq. 2 [11]}$$

## Effective Dose (ED) calculation

In this study used PCXMC software (version 2) was used to obtain organ doses. PCXMC software was developed by the Finnish Nuclear Safety and Radiation Center and is based on Monte Carlo calculations. In this software information such as

height, weight, peak voltage and film distance to the tube, ESAK value is recorded. The results of ESAK and ESD and patient data were analyzed by PCXMC software and the ED was extracted from the software. Based on these calculations, ED values for the current diagnostic digital radiographs were determined.

## Data analysis

Conspicuously, the distribution of the experimental groups was categorized according to age, sex, mean of weight and height, and the number of patients who participated in each age group. Obviously, the mean value, percentage, error variation coefficient, standard deviation, and minimum and maximum values were calculated by statistical package for the social sciences (SPSS) software version 16.0.

## Results

**Table 4** shows the statistical distribution of the average ESD in 15 radiography rooms for the 12 radiographic procedures. The Statistical distributions for all radiography examinations were obtained. In **Table 5** the summary of minimum, maximum, the ratio of maximum and minimum, and average dose (mGy) for each X-ray examination is presented. Distribution of means ESD for each x-ray examination is presented in **Table 5**. Means of patient's doses ranged from 0.97 mGy for the cervical spine (AP) in the 10-15 year group to 3.85 mGy for

the lumbar spine (lateral) for the adults. The ESD values for 12 digital radiography examinations in this study were compared with some international ESD values in **Table 6**. Additionally the comparison of the data obtained in this study to the results of the similar investigations conducted in Iran and other countries is shown in **Table 6**. EDs calculated using PCXMC software for each digital examination are listed in **Table 7**.

**Table 4. Average ESD (mGy) in 15 rooms for the 12 radiographic examinations for 2 age groups under study irrespective of sex.**

| X-ray room | Skull (PA) 10-15 year | Skull (PA) Adult | Skull (Lateral) 10-15 year | Skull (Lateral) Adult | Cervical spine (AP) 10-15 year | Cervical spine (AP) Adult | Cervical spine (lateral) 10-15 year | Cervical spine (lateral) Adult | Chest (PA) 10-15 year | Chest (PA) Adult | Chest (lateral) 10-15 year | Chest (lateral) Adult | Thoracic spine (AP) 10-15 year | Thoracic spine (AP) Adult | Thoracic spine (lateral) 10-15 year | Thoracic spine (lateral) Adult | Lumbar spine (AP) 10-15 year | Lumbar spine (AP) Adult | Lumbar spine (lateral) 10-15 year | Lumbar spine (lateral) Adult | Abdomen (AP) 10-15 year | Abdomen (AP) Adult | Pelvis (AP) 10-15 year | Pelvis (AP) Adult |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.89 | 1.15 | 0.76 | 1.49 | 0.89 | 1.53 | 0.96 | 1.03 | 0.79 | 0.59 | 1.31 | 1.22 | 1.33 | 1.51 | 2.11 | 2.63 | 1.79 | 2.27 | 2.93 | 3.78 | 1.48 | 2.61 | 1.49 | 1.71 |
| 2 | 0.51 | 0.52 | 0.71 | 0.54 | 0.65 | 0.49 | 0.73 | 0.69 | 0.68 | 0.58 | 1.19 | 1.11 | 1.23 | 1.50 | 1.56 | 1.93 | 1.73 | 1.86 | 2.78 | 2.99 | 1.20 | 1.49 | 1.24 | 1.39 |
| 3 | 0.97 | 1.51 | 0.8 | 1.05 | 0.93 | 0.82 | 1.12 | 1.31 | 1.11 | 1.62 | 1.35 | 1.18 | 1.38 | 1.68 | 2.11 | 2.59 | 2.31 | 1.89 | 3.49 | 3.12 | 2.01 | 2.12 | 1.35 | 1.61 |
| 4 | 1.12 | 1.26 | 0.88 | 0.94 | 1.06 | 0.62 | 0.79 | 1.23 | 1.08 | 0.77 | 1.27 | 1.56 | 1.29 | 1.61 | 1.71 | 1.98 | 2.46 | 2.57 | 3.58 | 5.58 | 1.64 | 2.50 | 2.02 | 1.74 |
| 5 | 1.09 | 1.29 | 1.03 | 1.38 | 1.12 | 1.42 | 1.17 | 1.21 | 0.83 | 1.72 | 1.39 | 2.17 | 1.43 | 1.64 | 2.00 | 1.96 | 2.21 | 2.31 | 4.28 | 2.42 | 2.11 | 2.05 | 1.61 | 2.37 |
| 6 | 0.72 | 1.48 | 1.16 | 0.98 | 1.02 | 0.68 | 1.04 | 0.91 | 1.04 | 0.86 | 1.23 | 1.47 | 1.26 | 1.52 | 2.09 | 1.88 | 2.42 | 1.99 | 3.39 | 3.43 | 2.05 | 1.64 | 2.00 | 1.57 |
| 7 | 0.91 | 1.25 | 0.94 | 1.08 | 1.11 | 1.31 | 0.95 | 1.06 | 0.89 | 1.28 | 1.36 | 1.15 | 1.48 | 1.60 | 2.14 | 1.79 | 2.17 | 2.11 | 3.32 | 3.89 | 1.38 | 1.77 | 1.47 | 1.69 |
| 8 | 0.93 | 1.11 | 1.10 | 0.71 | 1.00 | 0.73 | 1.03 | 1.44 | 1.00 | 0.68 | 1.26 | 1.69 | 1.41 | 1.55 | 1.66 | 2.89 | 2.22 | 2.31 | 3.66 | 3.49 | 2.04 | 1.65 | 2.03 | 1.53 |
| 9 | 1.23 | 1.09 | 1.14 | 0.64 | 0.81 | 1.08 | 1.01 | 1.52 | 1.00 | 0.61 | 1.29 | 1.61 | 1.34 | 1.53 | 2.12 | 1.99 | 2.25 | 2.21 | 2.86 | 3.68 | 1.69 | 1.92 | 1.52 | 1.66 |
| 10 | 1.19 | 1.18 | 1.55 | 1.23 | 0.89 | 1.67 | 1.17 | 0.85 | 1.00 | 0.81 | 1.26 | 1.33 | 1.42 | 1.8 | 2.15 | 2.69 | 2.74 | 3.15 | 4.22 | 4.33 | 1.51 | 1.66 | 1.59 | 1.52 |
| 11 | 1.82 | 2.31 | 1.89 | 2.09 | 1.15 | 1.82 | 1.18 | 2.71 | 1.21 | 2.11 | 1.49 | 3.01 | 1.51 | 2.00 | 2.26 | 2.71 | 3.09 | 6.05 | 4.99 | 6.25 | 2.37 | 2.78 | 2.11 | 3.25 |
| 12 | 1.29 | 0.85 | 1.09 | 1.03 | 1.07 | 0.91 | 1.01 | 1.21 | 1.06 | 1.33 | 1.38 | 2.02 | 1.45 | 1.57 | 1.42 | 1.86 | 2.18 | 2.39 | 3.77 | 3.68 | 2.23 | 1.67 | 1.39 | 1.44 |
| 13 | 1.26 | 0.98 | 1.18 | 0.89 | 0.79 | 1.6 | 1.03 | 1.00 | 1.04 | 1.06 | 1.32 | 1.21 | 1.47 | 1.63 | 1.59 | 1.99 | 2.25 | 2.09 | 3.69 | 3.22 | 2.00 | 2.33 | 1.48 | 1.72 |
| 14 | 1.35 | 0.94 | 0.99 | 1.46 | 1.03 | 1.05 | 0.91 | 0.89 | 1.09 | 1.01 | 1.27 | 1.48 | 1.39 | 1.61 | 1.63 | 2.67 | 2.16 | 2.41 | 3.55 | 3.91 | 1.39 | 1.75 | 1.77 | 1.61 |
| 15 | 1.18 | 1.03 | 1.08 | 1.89 | 1.12 | 1.88 | 0.87 | 1.01 | 1.04 | 0.87 | 1.45 | 1.28 | 1.36 | 1.58 | 2.01 | 1.98 | 2.91 | 3.24 | 3.89 | 4.06 | 1.41 | 2.02 | 1.44 | 1.41 |

**Table 5. Summary of mean, minimum, maximum and ESD values (mGy) for 2 age groups under study irrespective of sex.**

| X-ray examination | Age | Entrance Surface dose (mGy) Mean±SD | Minimum | Maximum | Ratio(Max\Min) |
|---|---|---|---|---|---|
| Skull (PA) | 10-15 year | 1.09±0.42 | 0.51 | 1.82 | 3.56 |
| | adult | 1.19±0.41 | 0.52 | 2.31 | 4.44 |
| Skull (lateral) | 10-15 year | 1.08±0.38 | 0.71 | 1.89 | 2.66 |
| | adult | 1.16±0.40 | 0.54 | 2.09 | 3.87 |
| Cervical spine (AP) | 10-15 year | 0.97±0.21 | 0.65 | 1.15 | 1.76 |
| | adult | 1.17±0.24 | 0.49 | 1.88 | 3.83 |
| Cervical spine (lateral) | 10-15 year | 0.99±0.30 | 0.73 | 1.18 | 1.61 |
| | adult | 1.20±0.27 | 0.69 | 2.71 | 3.92 |
| Chest (PA) | 10-15 year | 0.99±0.36 | 0.68 | 1.21 | 1.77 |
| | adult | 1.05±0.31 | 0.58 | 2.11 | 3.63 |
| Chest (lateral) | 10-15 year | 1.32±0.41 | 1.19 | 1.49 | 1.25 |
| | adult | 1.56±0.43 | 1.11 | 3.01 | 2.71 |
| Thoracic spine (AP) | 10-15 year | 1.38±0.49 | 1.23 | 1.51 | 1.22 |
| | adult | 1.62±0.51 | 1.50 | 2.00 | 1.33 |
| Thoracic spine (lateral) | 10-15 year | 1.90±0.69 | 1.56 | 2.26 | 1.44 |
| | adult | 2.36±0.67 | 1.79 | 2.89 | 1.61 |
| Lumbar spine (AP) | 10-15 year | 2.32±1.21 | 1.73 | 3.09 | 1.78 |
| | adult | 2.59±1.27 | 1.86 | 6.05 | 3.25 |
| Lumbar spine (lateral) | 10-15 year | 3.62±1.38 | 2.78 | 4.99 | 1.79 |
| | adult | 3.85±1.44 | 2.42 | 6.25 | 2.58 |
| Abdomen (AP) | 10-15 year | 1.76±0.65 | 1.20 | 2.37 | 1.97 |
| | adult | 1.99±0.67 | 1.49 | 2.78 | 1.86 |
| Pelvis (AP) | 10-15 year | 1.63±0.87 | 1.24 | 2.11 | 1.70 |
| | adult | 1.74±0.89 | 1.39 | 3.25 | 2.33 |

**Table 6. ESD (mGy) values of this study compared with some international reference dose for 12 digital radiography examinations**

| X-ray examination | Age | Entrance Surface Dose (mGy) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | This Study | Nahangi and Chaparian [19] | Kiljunen et al. [20] | Osei and Darko [21] | Mohsenzadeh et al. [11] | Ofori et al. [8] | Khoshdel-Navi et al. [10] |
| Skull (PA) | 10-15 | 1.09 | 3.32 | 0.12 | - | 0.94 | - | - |
| | adult | 1.19 | 4.38 | | 1.67 | 0.97 | - | 1.47 |
| Skull (lateral) | 10-15 | 1.08 | - | 0.53 | - | 0.82 | - | - |
| | adult | 1.16 | - | - | 0.76 | 0.86 | - | 1.01 |
| Cervical spine (AP) | 10-15 | 0.97 | - | - | - | 0.44 | - | - |
| | adult | 1.17 | - | - | 0.62 | 0.52 | 1.05 | 0.67 |
| Cervical spine (lateral) | 10-15 | 0.99 | - | - | - | 0.52 | - | - |
| | adult | 1.20 | - | - | 0.44 | 0.66 | 0.45 | 0.79 |
| Chest (PA) | 10-15 | 0.99 | 0.21 | 0.18 | - | 0.54 | - | - |
| | adult | 1.05 | 0.32 | - | 0.14 | 0.6 | 0.27 | 0.49 |
| Chest (lateral) | 10-15 | 1.32 | - | 0.47 | - | 0.71 | - | - |
| | adult | 1.56 | - | - | 0.94 | 0.85 | 0.43 | 1.06 |
| Thoracic spine (AP) | 10-15 | 1.38 | - | - | - | 1.23 | - | - |
| | adult | 1.62 | - | - | 2.21 | 1.44 | 3.10 | 2.33 |
| Thoracic spine (lateral) | 10-15 | 1.90 | - | - | - | 1.7 | - | - |
| | adult | 2.36 | - | - | 1.65 | 2 | - | 3 |
| Lumbar spine (AP) | 10-15 | 2.32 | - | - | - | 2.14 | - | - |
| | adult | 2.59 | - | - | 3.72 | 2.36 | 3.25 | 2.81 |
| Lumbar spine (lateral) | 10-15 | 3.62 | - | - | - | 3.37 | - | - |
| | adult | 3.85 | - | - | 6.28 | 3.62 | - | 4.28 |
| Abdomen (AP) | 10-15 | 1.76 | 2.20 | 0.63 | - | 1.53 | - | - |
| | adult | 1.99 | 3.36 | - | 1.82 | 1.65 | - | 2.07 |
| Pelvis (AP) | 10-15 | 1.63 | 2.20 | 2.54 | - | 1.35 | - | - |
| | adult | 1.74 | 3.36 | - | 1.57 | 1.43 | 1.31 | 1.90 |

**Table 7. ED (μSv) values for 2 age groups under study irrespective of sex**

| X-ray examination | Age | ED value (μSv) |
|---|---|---|
| Skull (PA) | 10-15 | 10.40 |
| | Adult | 13.35 |
| Skull (Lateral) | 10-15 | 18.80 |
| | Adult | 20.94 |
| Cervical spine (AP) | 10-15 | 33.88 |
| | Adult | 36.91 |
| Cervical spine (Lateral) | 10-15 | 15.04 |
| | Adult | 18.31 |
| Chest (PA) | 10-15 | 74.36 |
| | Adult | 80.87 |
| Chest (Lateral) | 10-15 | 62.22 |
| | Adult | 67.79 |
| Thoracic spine(AP) | 10-15 | 116.64 |
| | Adult | 131.45 |
| Thoracic spine (Lateral) | 10-15 | 112.53 |
| | Adult | 128.06 |
| Lumbar spine (AP) | 10-15 | 246.79 |
| | Adult | 298.02 |
| Lumbar spine (Lateral) | 10-15 | 159.68 |
| | Adult | 201.11 |
| Abdomen (AP) | 10-15 | 331.75 |
| | Adult | 378.46 |
| Pelvis (AP) | 10-15 | 177.23 |
| | Adult | 207.68 |

## Discussion

This study was the first to evaluate ED and ESD in digital radiology in Mazandaran province. In this study, ESD and the ED were evaluated in 12 common digital radiology examinations. The results of the parent study indicated a wide variation in patient's ED and ESD in the two age groups pediatrics and adults. In the mentioned 12 examinations, ESD and ED increase with age. It can be suggested that these variations are a result of radiation conditions of the examinations, quality control of the x-ray machines, FFD, methods of radiography, and types of equipment.

The highest ESD was related to the lumbar spine (lateral) examination and the least to the skull (lateral) examination. Means of patient's ESD ranged from 0.97 mGy for cervical spine (AP) in the 10-15 year group to 3.85 mGy for lumbar spine (lateral) in the adults. High levels of ESD in the lateral view are attributed to the increase in the thickness of the examined organ relative to the other view. This results in the increase in the radiation condition. The mean ESD values chest (PA) obtained in this study was 1.05 mGy for adults, that is higher than other studies, for example, the study of Mohsenzadeh and Nahangi H et al their mean ESD values chest (PA) for adults are 0.61 and 0.32, respectively.

**Table 7** shows the lowest ED for the 10-15 year range in skull (PA) examination is 10.40 (μSv) and the highest ED for adults in the abdominal (AP) examination is 378.46 (μSv). The results of this study show that the ED values for the two age groups of 10-15 years and adults in the abdomen (AP), pelvis (AP), and lumbar spine (AP) techniques were respectively higher than the other techniques. The reason for the high ED value in these three radiographic examinations is firstly due to the high X-ray examination parameters and then a large number of sensitive organs in the radiation field of these techniques. In both techniques, namely the lumbar spine (AP) and abdomen, most of the internal organs are irradiated. Since the most effective factors on the amount of ESD and ED in digital radiology examination are field size, kVp difference, FFD, etc, best practice protocols can be used to reduce the effective contribution [15].

In the case of FDD, these values varied in different centers and varied on average from 90 cm to 180 cm. This survey reveals a significant variation in radiological practice including. Ostensibly, the X-ray examination parameters which are set by radiologic technicians could change in a wider range, for example, in adults, the mAs vary from 10 mAs to 21 mAs for chest (PA) examinations, and from 17 mAs to 40 mAs for abdomen examinations.

Khoshdel et. al. [10] reported that the minimum and maximum ESD were 0.49 mGy, and 4.28 mGy for chest (PA) and lumbar (lateral), respectively [10]. In this study, the minimum and maximum ESD were found to be 0.97 mGy and 3.85 mGy in the cervical (AP) and lumbar (lateral), respectively. As can be seen, the values are not much different.

In the study by Balonov [16] published on the ED and risks of X-rays it was stated that the highest ED was related to the abdomen (AP) and lumbar (AP) techniques and th(e lowest was related to the skull (AP) [16]. These results are similar to our study. The abdomen (AP) is used because it has the most sensitive organs and also a larger field. And in the lumbar (AP), ED increases due to the high kVp and mAs.

Studies of Sulieman et al. [17] and Kutanzi et al [18] were conducted on the ED and radiation effects on children and have shown that the sensitivity to the radiation in childhood is 2-3 times higher than the adults. In consistence with these results, this study indicates that the age group of 10-15 years is more sensitive than the adults due to the high cell division and longer life span [17,18].

The results of this study are limited to Mazandaran province and cannot be generalized to the whole country.

## Conclusion

According to the results obtained in this study, it can be concluded that the ED and ESD differences are due to the application of the procedures (such as kVp and mAs, radiologist skills, field, etc.). Therefore, considering the importance of radiation conditions on patient ED and ESD and image quality, these conditions can be chosen to reduce the patient ED and ESD as much as possible while maintaining image quality.

General, low kVp and high mAs techniques may have increased the dose. More extensive studies on the parameters affecting the dose as well as the introduction of more advanced devices can greatly reduce the patient ESD and radiation risk. Implementation of a QA program, relying on detector quality and inspection of other radiographic devices, can be a reasonable step in reducing patient dose. In addition, a medical physicist is recommended to achieve these goals in medical centers.

## Acknowledgment

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