

## Evaluation of organ Radiation Doses during Pelvic X-Ray Examinations in Medical Imaging Centers

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ARTICLE INFO	ABSTRACT
<p><b>Article type:</b> Original Article</p> <hr/> <p><b>Article History:</b> <b>Received:</b> 17 Sep 2025 <b>Accepted:</b> 10 Nov 2025</p> <hr/> <p><b>Keywords:</b> Radiation Dose; Pelvic X- ray; Medical Imaging; Organs Dose Assessment; PCXMC 2</p>	<p>The radiographic examination of the pelvis is a routine procedure in the medical imaging facilities to measure pathological processes like fractures, arthropathy or degenerative disease. However, since X-ray imaging involves the use of ionizing radiation, there is a reasonable possibility of subjecting the sensitive organs of the pelvis, such as the gonads, bladder, rectum and bone marrow to harmful doses of radiation. The current study aimed at determining the levels of organ-specific radiation dose of a cohort of 100 adults who underwent conventional anteroposterior pelvic radiography in three different imaging centers based in Erbil, Iraq. The exposure variables (kVp, mAs, filtration, source-image distance) were measured with a Nomex multimeter and estimates of organ dose were obtained with the PCXMC 2.0 Monte Carlo simulation package. The effective dose rates of the vital organs ranged between 1.04 mSV onto the colon and 3.02 mSV onto the prostate. These findings demonstrate the urgency to unify and align imaging procedures and even guarantee their correspondence to diagnostic reference levels, reducing stochastic threats and preserving diagnostic effectiveness.</p>
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## Introduction

Evaluating several medical conditions impacting the pelvic area requires pelvic examinations comprising X-rays, CT scans, and fluoroscopy-diagnostic imaging modalities. But occasionally these tests reveal ionizing radiation, which has possible health risks particularly to organs sensitive to radiation including the bladder, gonads, rectum, and bone marrow. In medical imaging, measuring radiation doses is rather important since long-term or repeated radiation exposure in this area has been connected to a higher risk of tissue damage, genetic changes, and possibly cancer (1).

Several elements determine the degree of radiation risk: type of imaging modality, patient anatomy, imaging parameters, and radiation protection policies (2). Although modern imaging methods seek to reduce radiation exposure by means of dose optimization and shielding, ongoing radiation dose monitoring and evaluation are still absolutely vital for guaranteeing patient safety (3). The amount of radiation the skin absorbs at the point the X-ray beam enters the patient's body is known as entrance skin dose (ESD) (4). Usually expressed in mGy, it is a major determinant of patient radiation exposure in diagnostic imaging (5).

It encourages maximization of dosage and adherence to the ALARA (as Low as Reasonably Achievable) standards (6). Especially under fluoroscopy, when high ESD values are applied, tissue damage or erythema to the skin may occur (7).

Backscatter factors and dose-area product (DAP) are used to calculate ESD analytically. ESD, a core quantity in medical imaging, satisfies the patient safety and diagnosis quality. The effective dose (ED, in mSv) is an indicator of the overall risk of radiation exposure to the body and is described in Equation (1). The recommendations of the International Commission on Radiological Protection (ICRP) are based on the sensitivity of each organ to radiation-induced cancer or harm as well as on the amount of radiation each organ absorbs.

$$\text{Effective Dosage (ED, mSv)} = \sum (H_T \times W_T) \dots \dots (1)$$

$H_T$  denotes the dose for a particular organ or tissue, while  $W_T$  represents the tissue weighting factor according to ICRP

guidelines. Long-term radiation hazards including cancer can be estimated with the help of risk assessment. In radiological protection, effective dose is a crucial value that balances possible radiation hazards with possible benefits for diagnosis. Given the high radiosensitivity of pelvic organs, particularly gonads and bone marrow, organ dose assessment provides more actionable data for risk mitigation than effective dose alone, especially in reproductive-age patients.

The latest version of PCXMC (PCXMC version 2.0) was released in 2008. Software developed by STUK (Radiation and Nuclear Safety Authority in Finland), PCXMC 2.0 is Monte Carlo-based software used for radiation-induced cancer risk, focusing on pelvic examinations (3). The software provided detailed estimations for pelvic organs (bladder, colon, liver, stomach, kidney, spleen, small intestine, gonads, ovary, and uterus) that help assess radiation risks and optimize exposure settings to minimize patient dose (3). It simulates radiation transport through a mathematical anthropomorphic phantom, representing different patient sizes, ages, genders (male or female phantom selection), body sizes (phantom scaling), organ positions, and tissue thicknesses. Within a virtual patient phantom, it tracks the primary and scattered radiation as it propagates through the body. By accurately setting patient and technical factors, PCXMC 2.0 ensures precise radiation dose estimation, helping to optimize X-ray examination protocols for safety and effectiveness. This study aims to assess the radiation dose distribution among pelvic organs during X-ray examinations in medical imaging centers. By analyzing dose levels and identifying risk factors, the findings can contribute to improved radiation safety measures, optimized imaging techniques, and better compliance with radiological protection guideline.

## Materials and Methods

The study was a cross-sectional study that involved 100 adult patients (age 20 years and older) who received standard anterior-posterior (A -P) pelvic radiography in three public imaging centers in Erbil between January and June 2023. Technical parameters of each examination recorded

were tube voltage (kVp), current-time product (mAs), total filtration (3mmAl equivalent), source to image distance (SID) and X-ray field size using a calibrated Nomex Multimeter (PTW, Freiburg). Demographic (age, sex, height, weight) and anatomical thickness (measured at the iliac crest) of the patients were also recorded. The estimation of organ and effective doses was done using PCXMC 2.0, a Monte Carlo software that was used to model the radiation movement using mathematical phantoms. Parameters included input such as measured kVp, mAs, filtration, SID, beam projection (A -P) and patient specific age, sex, and body thickness. The software has automatically chosen the right phantom and calculated doses to the target organs based on ICRP-103 tissue weighting factors. Entrance skin dose (ESD) was derived from air kerma measurements using the Nomex Multimeter. PCXMC 2.0 is a Monte Carlo simulation software used for estimating radiation dose in medical X-ray imaging. To calculate the effective and organ doses, the input factors must be provided. Voltage (kVp) determines the energy of the X-ray beam. Tube current-time product (mAs) defines the amount of X-ray exposure. Beam Filtration (3mm Al) specifies the additional filtration affecting beam quality. X-ray field size (cm × cm) is the dimensions of the irradiated area. Source-to-image distance (SID) (cm) is the distance from the X-ray tube to the detector. Beam projection (pelvic AP) defines the orientation of the X-ray beam relative to the patient. The Patient Age and

Size (Phantom Selection) model serves as a tool for estimating organ doses.

The body part examined is the pelvic region, which helps determine the exposure area. Beam collimation describes the restriction of the beam to reduce unnecessary exposure. Exposure geometry (C-arm, fixed tube, etc.) refers to the specific configuration of the imaging system. Scattered radiation consideration includes secondary radiation effects. Number of exposures is the number of repeated scans affecting cumulative dose.

Weighting factors for tissues (ICRP models) are used to calculate effective dose from organ doses. Backscatter factor accounts for radiation reflected from the patient's body back into the detector. Each of these parameters influences the calculated effective and organ dose, making them critical for accurate dosimetry in PCXMC 2.0. The SPSS v22 was used to comment on the data. The findings are reported in the form of mean +/ - standard deviation (SD) and range (minimum -maximum)

## Results

### 3.1 Patient demographic features

Presents demographic data for male and female patients, including age, weight, body mass index (BMI), and patient thickness. Because body thickness and BMI affect how much radiation is needed for proper imaging, these data are essential for dose assessment. It is easier to correlate radiation dose results with patient features when these variances are understood.

**Table 1:** Patient demographic features

Demographic data	Descriptive statistics	Male	Female	Average values for all patients
Age (yrs.)	Min	28.0	22.0	22
	Max	70.0	80.0	
	Mean± SD	42 ± 0.32		
Weight (kg)	Min	55.0	50.0	50
	Max	130.0	120.0	
	Mean± SD	83 ± 0.02	80 ± 0.06	
Body mass index (kg/m <sup>2</sup> )	Min	20.0	18.0	18
	Max	40.0	42.0	
	Mean± SD	27 ± 0.42	29 ± 0.35	
Patient thickness (m)	Min	0.2	0.2	0.2
	Max	0.4	0.5	
	Mean± SD	0.30 ± 0.05	0.33 ± 0.05	

### 3.2 Descriptive statistics of ESD

Outlines Entrance Skin Dose (ESD) values across different age groups and genders.

Age-related variations in radiation dose are shown in the results, which could be explained by anatomical variations and

technical exposure conditions. Such research reaffirms the significance of age-

specific radiation protection and supports customized dose optimization tactics.

**Table 2:** ESD (mGy) descriptive data by gender and age group

Age Years	Male Max	Min	Average+SD	Female Min	Average+SD
20 - 30	23.4	3.6	7.42	3.7	5.39 + 1.6
31 - 40	20.3	2.5	6.23	2.8	5.21 + 2.4
41 - 50	15.2	3.7	3.43	1.67	4.42 + 0.6
51 - 60	17.5	2.8	4.36	2.88	6.63 + 0.23
61 - 70	20.2	2.9	6.18	3.52	7.19 + 0.05

**3.3 Effective dose for female**

Summarizes organ-specific effective doses for female patients. Relatively larger doses were given to organs such as the uterus, bladder, and ovaries, indicating their

vulnerability during pelvic imaging. These numbers help determine danger and make sure that organs that are sensitive to radiation are protected.

**Table 3:** PCXMC-calculated effective dosage for females

Organ	Effective Dose (ICRP 103), mSv
Colon	1.04±0.01
Kidney	1.02±0.02
Muscles	1.56±0.02
Ovaries	2.16±0.03
Urinary Bladder	2.26±0.02
Uterus	2.13±0.01
Total Body	0.42

**3.4 Effective dose for male**

Provides organ dose data for male patients. The prostate and testicles are shown to receive higher doses, underlining the necessity of shielding these organs

during pelvic radiography. The data are essential for evaluating gender-specific radiation risks and tailoring protective protocols accordingly.

**Table 4:** Effective dose for male calculated by PCXMC

Organ	Effective Dose (ICRP 103), mSv
Colon	1.06±0.09
Kidney	2.03±0.04
Muscles	1.30±0.01
Urinary Bladder	1.56±0.01
Prostate	3.02±0.04
Testicles	2.13±0.01
Total Body	0.75±0.03

**3.5 Compare between Present Effective Dose (mSv) and other Published literature**

Comparison places the current study’s findings in the context of previous research. The present effective dose is relatively

moderate but higher than some earlier reports. This comparison supports benchmarking and the need for continual evaluation of imaging practices to maintain doses within acceptable reference levels.

**Table 5:** Compare between Present Effective Dose and other Published literature

Study	Total Effective Dose (MSV)
Present study	0.5
Roch et al. (2018)	0.7
Suliman et al. (2007)	0.023
Compagnone et al. (2005)	0.29

### 3.6 Risk of Exposure for female

Presumably assesses the lifetime risk of fatal cancer from radiation exposure to specific female organs.

It is crucial for understanding long-term health impacts and refining risk-benefit analyses in radiological examinations.

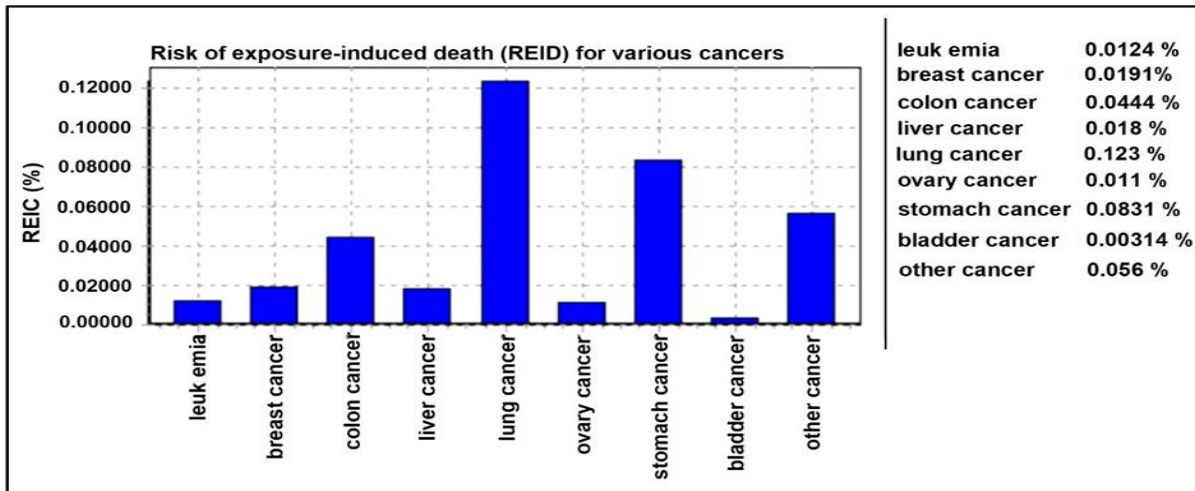


Figure 1: Risk of exposure-induced death calculated by PCXMC 2.0 software for female

### 3.7 Risk of Exposure for male

Estimated cancer mortality risks for males based on organ-specific doses. Highlighting the radiation sensitivity of organs like the

bladder and colon reinforces the importance of minimizing exposure through optimized imaging protocols.

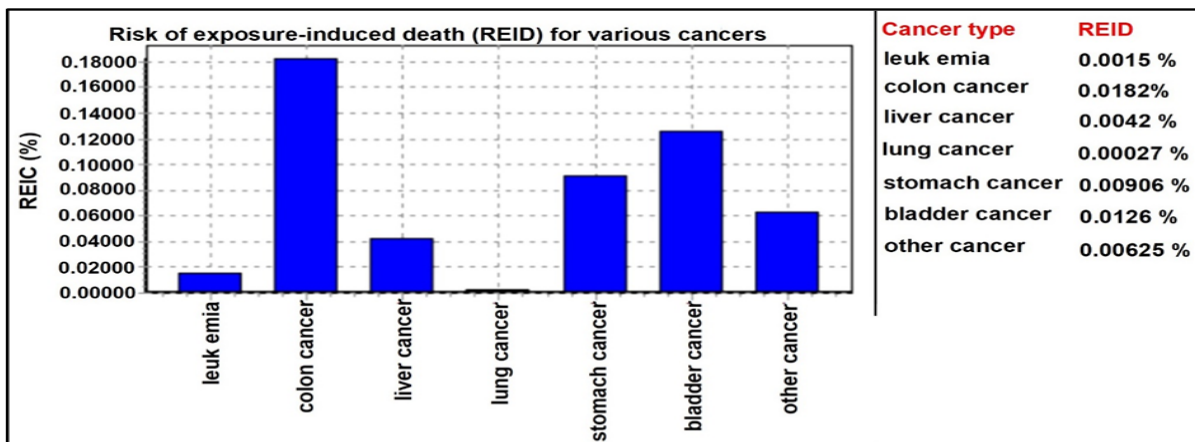


Figure 2: Risk of Exposure – induced death calculated by PCXMC 2.0 software for males

### Discussion

In the study, the radiation dose in the organs was measured in 100 adult patients who were subjected to a normal anteroposterior pelvis radiography in three imaging centers in Erbil. Dose evaluation has been conducted through direct beam measurements with Monte-Carlo calculations with PCXMC 2.0 program. The findings indicate that the pelvic organs are not negligently exposed and the mean

absorbed doses of the urinary bladder of 2.26 mSv in female patients and the prostate in male patients are 3.02 mSv. Such findings are anatomically viable with central organs located in the primary X-ray beam such as the bladder and prostate being more prone to dose deposition than the peripheral tissue (8 ,9). Remarkably, the prostate was subjected to a larger dose (2.13mSv) than the testes when this was compared to the prostate; this is because of its direct

placement in the collimated field in the anteroposterior projection whereas the testes are not in the collimated field and are rather subjected to scattered radiation. The data, therefore, refute the existing assumption that thin organs always receive more dose and emphasize the importance of beam geometry in determining dose distribution.

The effective dose in the aggregate measurements of the study was 0.42 mSv in female patients and 0.75 mSv in male patients, which is in range with those of Suliman et al. (0.023 mSv) (7) and Compagnone et al. (0.29 mSv) (10) but close to that reported by Roch et al. (0.70 mSv) (11). Such differences can probably be explained by the differences in the age of equipment, radiograph exposure policies, and the absence of standard diagnostic reference levels (DRLs) in some clinical settings. The significant inter-center variation in entrance skin dose of 1.7 to 23.4mGy also points to the inconsistent optimisation plans, such as heterogeneous collimation, different source-to-image distance (SID), and the lack of automatic exposure control (AEC).

This can result in dose variability and is incompatible with the principle of ALARA, particularly in the case of younger patients, where the stochastic risk burden is cumulative over a lifetime (6).

The higher dose rates in the radiosensitive organ structures, namely in ovaries (2.16 mSv) and testes (2.13 m Sv) and in the bladder reveal the need to have protection strategies that are gender-specific. Although the application of gonadal shielding has been recommended in patients who are below the age of 50 years, its inconsistent use in the everyday practice remains a significant issue (12). Also, the inability to periodically collimate exposures to the pelvic brim in some imaging centres was probably the cause of unnecessary irradiation of adjacent tissues.

The technical parameters can be fine-tuned i.e. by increasing the distance between the source-image to take advantage of the inverse square law or by choosing a higher tube voltage in conjunction with a lower mAs and thus can result in a significant reduction in patient dose without loss of

image quality (9). These methods are especially relevant in resource limited environments when complex tooling like automatic exposure control might not be available.

The PCXMC 2.0 which is a validated Monte Carlo simulation package was used to obtain the organ doses commonly used in estimating the dose of patients in diagnostic radiology (3). This methodology provides reliable organ-specific dose values, and is based on mathematical phantoms which make assumptions of a normal anatomical structure, thus ruling out inter-individual variations in organ localisation, adipose tissues distribution, or pathological changes. The study was only restricted to three radiology centres in a single city and as such, may have constrained the generalisation of the findings to other geographical areas with different instrumentation or procedures.

Despite the above limitations, this research provides useful regionally obtained dosimetric data that can be used as a baseline on the establishment of national diagnostic reference levels (DRLs) to pelvic radiography in Iraq, a country that currently does not have such parameters. By matching organ-specific dose risks with technical determinate to be modified, the current results will provide a pragmatic introduction of framework of quality management, i.e., the standardisation of collimation practices, implementation of gonadal protection to persons of reproductive age, and systematic review of exposure indices against achievable DRLs. These measures are in compliance with the International Atomic Energy Agency recommendation on patient dose optimisation (13) and the promotion of a safety culture whereby diagnostic efficacy is ensured and superfluous exposure of radiation is kept at minimum.

To summarise, this study has confirmed that even normal radiographs of the pelvis give measurable amounts of radiation to vital organs. The absolute risk of having a single examination is not that significant though the cumulative effect of recurrent imaging, particularly in younger cohorts, is important to motivate the importance of proactive dose management.

Through specific training, protocol standardization, and following evidence-

based optimization plans, the imaging centres will be able to achieve significant patient safety improvement without impairing the diagnostic integrity.

### Conclusion

Most of the organs in the pelvis are highly radiosensitive with a lot of concern being raised in the process of taking X-rays. In the initial experiment evaluate radiation doses at specific body organs in adult patients during standard pelvic radiography, the authors found the most extreme doses in the prostate (3.02 mSv) and urinary bladder (2.26 mSv). Such data highlight the necessity to focus on optimization of the protocol to reduce stochastic risks without reducing diagnostic utility. Three specific actions that we would suggest include: (1) the strict collimation of the pelvic brim; (2) regular use of gonadal shielding in patients under the age of 50; and (3) a regular audit of exposure parameters to local diagnostic reference levels. The compliance with the ALARA principle is not a suggestion, but a vital element of long-term patient safety. A regular adoption of these practice will help imaging centres to a higher balance in terms of quality and radiation protection of the image.

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We confirm that this work didn't receive any funding.

### Ethical clearance

This study is based on original work that has not been published or submitted elsewhere for review.

### Conflict of interest

The authors declare that they have no financial or other conflicts of interest.

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