Evaluation of Radiation Doses for Patients Undergoing Abdominopelvic Computed Tomography Examination in Palestine

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As a diagnostic modality, computed tomography (CT) delivers higher radiation doses compared to other imaging modalities. CT requests increase rapidly, hence radiation dose assessment and protection are important. This study assessed the patient radiation dose and estimated organ doses for patients undergoing abdominopelvic CT examination. This study was conducted at three radiology departments equipped with 128-slice CT machines (Philips iCT) calibrated according to international protocols in the West Bank, Palestine. A total of 200 patients underwent abdominopelvic CT examinations. Organ and effective doses were evaluated using a web-based Monte Carlo CT dose calculator: WAZA-ARI dosimetry system that has selected according to tomographic parameters. For all patients, the colon dose ranged from 5.4 to 26.1 mGy per examination, with a mean colon dose of 14 mGy. The effective dose from abdominopelvic CT scan per examination ranged from 2.04 to 8.4 mSv with an average of 4.8 mSv. It is essential to improve radiographers’ knowledge of radiation dose in CT protocols and to receive continuous education and training regarding radiation dose optimization and reduction strategies.

KEY WORDS: radiation, dose, abdominopelvic, computed, tomography, palestine.

I INTRODUCTION

X-ray imaging procedures use ionizing radiation to generate the images of the body, and this ionizing radiation produces several adverse biological effects including cell death, radiation-induced changes in the genes responsible for cell growth, abnormal nuclear structure, deoxyribonucleic acid damage, and cancer induction.1) Regarding high radiation doses, there are specific dose thresholds to induce radiation risks in several human tissues.2) Since the introduction of computed tomography (CT) in 1971, its use in medical imaging has increased widely over the past several decades.3) The number of scanners is dramatically increasing with continuous and wide improvements in image quality, temporal and spatial resolutions, accuracy, and scan times.4, 5) Although CT technology improves significantly and provides a more accurate diagnosis of several diseases compared to other imaging modalities,6) it raises a health concern for individuals receiving high radiation dose during scanning, which is both age and sex dependent.7) It is estimated in a study in the US that approximately 29,000 future cancers could be related to CT scan.8, 9)

Various studies reported a wide variation in patient radiation doses.1, 7–14) Furthermore, it has been reported that patient effective doses during abdominopelvic CT examinations range between 5.4 and 19.8 mSv.14) Patient radiation doses during abdominopelvic CT examination and detriment risk data are limited; hence, it is necessary to evaluate patient radiation doses to justify the use of CT, optimize patient protection, and balance the risks versus benefits of CT examination.2, 6) According to the ICRP guidelines, the radiosensitivity of cells, organs, or tissues to the detrimental effects of ionizing radiation varies for different tissues and organs depending on age and physical and biological factors.2, 9) Lung, breast, stomach, together with active bone marrow are the most radiosensitive tissues, whereas the remaining tissues have a variety of sensitivities.2) The stomach, colon, and bladder are directly situated in the field of view for abdominopelvic CT scans. It is essential to estimate organ doses during CT examination. Radiation dosimetry is recommended in assessing patient radiation dose to improve the clinical practice of CT.

The assessment method of radiation dose received during CT examinations have been described in various literature. The direct method in assessing patient dose is to measure radiation organ doses using patient-like phantoms utilizing specific body region coefficients and dose length product (DLP). These coefficients can be used to convert DLP values to effective doses.15) Another method for the estimation of patient dose in CT is by Monte Carlo simulations16) using patient and scanner
characteristics. Effective and organ doses can be calculated using normalized data based on Monte Carlo simulations as mentioned in some literature. The elevated patient radiation dose in CT is a product of multiple factors such as overlapped scans, repeated examinations, inappropriate exposure parameters, and possible larger scan volume coverage. This study aimed to assess the patient effective and organ doses during abdominopelvic CT examination in the West Bank, Palestine.

II MATERIALS AND METHODS

2.1 Computed tomography machines and patient radiation dose indicators

The Three 128-slice CT scanners (MSCT, Philips Brilliance iCT, Amsterdam, Netherlands) were installed in 2010. The MSCT comprises detector rows ($128 \times 0.625$ mm) with a maximum gantry rotation speed of 0.5 s. All quality control tests were performed on the machines prior to data collection. A quality control test of the accuracy of the CTDI display which is being used to quantify patient dose was carried out using an acrylic cylinder phantom with an ion chamber. All the parameters were within acceptable ranges. Radiation dose estimates were determined using the volume CT dose index (CTDIcon) in mGy and the dose-length product (DLP) in mGy*cm as provided on the scanner console. All abdominopelvic CT scans were made in the helical mode. Organ doses were estimated using the WAZA-ARI version 2 CT dosimetry system, which is a web-based open Monte Carlo simulation software for CT dose calculations. WAZA-ARI v2 enables users to provide CTDI and DLP data according to each CT scanner, in addition to the assessment of organ doses. It includes a library of patient models that cover both male and female patients of various ages and body weights. BMI was calculated from the weights and heights (height in m$^2$). Calculated body mass indices for all patients in the study were within acceptable ranges. Radiation dose was evaluated in one of the most frequently requested CT studies: adult abdominopelvic CT performed without contrast material (single phase, unenhanced). A total of 200 adult patients (61.5%, men; 38.5%, women) underwent abdominopelvic CT examination (Table 1). Patient-related parameters (age, sex, body mass index (BMI)) and radiation exposure-related parameters (tube current (mA), exposure time, tube potential (kVp), slice thickness, and number of slices) were also considered.

| Age (year) | BMI (kg/m$^2$) | Tube voltage (kVp) | Tube current (mA) | Pitch | Collimation (mm) | Slice Thickness (mm) |
|-----------|----------------|-------------------|------------------|-------|-----------------|-------------------|
| Mean ± SD | Mean ± SD      | Mean ± SD         | Mean ± SD        |       |                 |                   |
| (Min–Max) | (Min–Max)      | (Min–Max)         | (Min–Max)        |       |                 |                   |
| Men       | 45 ± 17        | 120               | 254 ± 78         | 1     | 128 × 0.625     | 5                 |
| 18–79     | 27 ± 4         | 17–41             | 105–364          |       |                 |                   |
|           | 20–41          | 120               | 129–348          |       |                 |                   |
| Women     | 47 ± 17        | 120               | 245 ± 63         | 1     | 128 × 0.625     | 5                 |
| 18–80     | 27 ± 5         | 20–41             | 129–348          |       |                 |                   |

Table 1 Image acquisition parameters according to sex.
patient radiation doses with respect to CTDIvol (mGy), DLP (mGy*cm), effective dose, and colon organ dose values for all patients are shown in Table 2.

The mean patient and organ radiation doses according to sex showed some variation. This difference is possibly attributed to several exposure parameters, which were based on the patients’ demographic data and covered scanning volume.

### IV DISCUSSIONS

#### 4.1 Patient dosimetry

CT imaging technology significantly contributed to the establishment of diagnosis of various diseases; however, the patient radiation dose in CT is significantly higher than that in other radiologic examinations. Table 1 represents the abdominopelvic CT scan parameters. A constant voltage potential (120 kVp) was used with variable mA (105 to 364), which is possibly attributed to different patient sizes. Additionally, DLP values varied considering the differences in mA and covered scan volume. Generally, the radiation dose is directly proportional to mA. Therefore, a reduction in the tube current will reduce the patient radiation dose. The mean and range values of CTDIvol (mGy), DLP (mGy*cm), effective (mSv) and organ doses (mGy) are shown in Table 2.

There are several factors that affect the radiation dose from abdominopelvic CT examination including X-ray tube voltage and current, tube rotation time, slice thickness, pitch, and the utilization of dose reduction protocols, if available.

#### 4.2 Organ dose calculations

Certain radiosensitive organs are directly irradiated during abdominopelvic CT imaging, such as the stomach, colon, uterus, and prostate. The stomach, colon, uterus, and prostate are expected to receive high radiation doses due to their higher radiosensitivity. Additionally, colon has larger surface area compared to other abdominopelvic organs.

In this study, the colon received mean radiation doses of 14 mGy, for both men and women. However, the stomach dose in women was a bit higher (16.6 mGy) compared to men (14 mGy). These values are relatively higher compared to other abdominopelvic organs.

### CONCLUSIONS

Abdominopelvic CT examination, which is frequently requested, is considered a high radiation dose procedure. Radiosensitive organs receive a significant radiation dose during CT examinations. With appropriate evaluation of patient radiation dose, radiation awareness will be improved. The radiation exposure should be reduced and kept as low as reasonably achievable. CT procedure is operator-dependent, and continuous training in CT use and radiation safety is crucial. Repetition of examinations should always be avoided. A Palestinian national survey is highly recommended to establish the national diagnostic reference levels for various CT examinations.

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### CONFLICT OF INTEREST DISCLOSURE

The authors indicated no conflicts of interest.

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**Table 2** Patient effective and organ doses during abdominopelvic CT examinations.

| Gender | CTDIvol (mGy) | DLP (mGy*cm) | Effective dose (mSv) | Colon dose (mGy) | Stomach dose (mGy) | Prostate/Uterus dose (mGy) |
|--------|---------------|--------------|---------------------|----------------|-------------------|--------------------------|
| Mean ± SD (Min–Max) | Mean ± SD (Min–Max) | Mean ± SD (Min–Max) | Mean ± SD (Min–Max) | Mean ± SD (Min–Max) | Mean ± SD (Min–Max) | Mean ± SD (Min–Max) |
| Men    | 8 ± 3         | 350 ± 113    | 5 ± 2              | 14 ± 5         | 14 ± 5           | 10 ± 4                   |
|        | 3.2–12.9      | 136–513      | 2.04–7.7           | 5.4–20.4       | 3–20.2           | 3.7–15.8                 |
| Women  | 8.1 ± 2.4     | 306.2 ± 91.9 | 4.6 ± 1.4          | 14.1 ± 4.2     | 16.6 ± 5.1       | 10.4 ± 3.4               |
|        | 3.9–14.7      | 148.1–556.7  | 2.2–8.4            | 6.9–26.1       | 8.1–30.5         | 4.8–19.4                 |
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