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Note

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

Hussein ALMASRI*1, †, # and Wala INAYYEM*2

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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 male and female tissue equivalent phantoms of various ages and sizes. For every patient, a corresponding phantom was 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,3, 4) it raises a health concern for individuals receiving high radiation dose during scanning, which is both age and sex dependent.6) It is estimated in a study in the US that approximately 29,000 future cancers could be related to CT scan.3, 7)

Various studies reported a wide variation in patient radiation dose.3, 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, 5) 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

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[*1] Medical Imaging Department, Faculty of Health Professions, Al-Quds University; Jerusalem, Palestine, P. O. Box 51000.
[*2] Faculty of Public Health, Al-Quds University; Jerusalem, Palestine, P. O. Box 51000.
[†] Present Address: Department of Medical Imaging, School of Health Professions, Al-Quds University; Jerusalem, Palestine, P. O. Box 51000.
[#] Corresponding author; E-mail: halmasri81@staff.alquds.edu

characteristics.[17] Effective and organ doses can be calculated using normalized data based on Monte Carlo simulations as mentioned in some literature.[18, 19]

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 × 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 (CTDIvol) 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.[20] WAZA-ARI v2 enables users provides 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. It can be used with many CT scanner models and utilizes both ICRP-60 and ICRP-103 weighting schemes on effective dose.[20] The scan parameters that were selected in the WAZA ARI v2 for effective and organ dose calculations in addition to the scanner model include filter type, tube potential (kV), rotation time (s), pitch factor, beam width (mm), and gender. The selection of the used phantom size for dose calculation depend on patients' body sizes (BMI). The WAZA ARI v2 provides an additional option within the phantom item, which is "Adult optional phantom." By selecting "Adult optional phantom," two additional inputs appear for inserting patient's height and weight. Therefore, a user may select from WAZA ARI v2 standard Japanese phantoms, or choose to insert additional adult optional phantom size using patient's height and weight parameters. The former can be applied to Japanese study conditions, whereas the latter can be used for international studies on nations with different body sizes. The scan range (FOV) was set for each patient by entering the scanning range begin and end positions (mm) in WAZA ARI v2. The scan range begin and end positions (superior and inferior borders of the scan range) were taken from each patient CT scan details and entered in the WAZA ARI v2 to determine the scan length.

2.2 Organ and effective dose calculations

Patient exposure parameters and DLP (mGy*cm) were used to estimate both the effective (E) and organ equivalent doses (H) using the WAZA-ARI version 2 software. The organ equivalent dose (mSv) is calculated using the following equation:

$$H_T = \sum_R W_R \times D_{T,R} \qquad (1)$$

where $D_{T,R}$ indicates the mean absorbed dose to the organ (T) from radiation (R) and W_R is the radiation-weighting factor (W_R for X-ray is 1).[2] DLP and CTDIvol were extracted from a dose summary page which appears on CT scanner monitor for every scanned patient. DLP indicates the dose imparted to a patient and is used to calculate the effective dose in mSv from abdominopelvic CT by being multiplied with an appropriate conversion factor (0.015).[21]

III RESULTS

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.

The age, weight, and height of patients ranged from 18 to 80 years, from 54 to 110 kg, and from 150 to 186 cm, respectively. BMI was calculated from the weights and heights of each patient based on the following equation BMI: weight/(height in m^2). Calculated body mass indices for all patients in the three radiology departments ranged from 17 to 41 kg/m^2.

The mean age of the 200 patients was 45 and 47 years for men and women, respectively, as presented in **Table 1**. Tube potential and pitch were used with auto mA settings, and the range for the used mA is shown in **Table 1**. The measured

Table 1 Image acquisition parameters according to sex.

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

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 value 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 with the values observed in a previous study.[22] SABARUDIN et al.[22] reported that the stomach and colon received average radiation doses of ~9 and 11 mGy, respectively. In this study, the mean radiation doses received by the uterus are comparable to the previously reported average doses received by the uterus (12.10 ± 2.57 mGy) in a previous study.[23] It should be noted that the number of CT scans in a given study is an important factor in determining the radiation dose. METTLER et al.[24] reported that patients undergoing abdominopelvic CT examination virtually undergo more than one scan during any single examination. DE MAURI et al.[25] reported that the average number of scans per single CT examination is 2.4 for abdominopelvic CT. Generally, the published estimates of typically effective radiation doses in CT procedures are reported for a single CT scan. The simple recording of a CT examination without the exact number of scans per examination may lead to a serious underestimation of both the effective and organ doses. Other medical imaging alternatives should be considered instead of CT, such as magnetic resonance imaging.

Certain dose reduction strategies aimed at reducing patient radiation dose from CT examination, such as the use of tube current (mA) modulation,[26] iterative reconstruction techniques,[27] patient radiation dose optimization protocols, staff awareness, and use of advanced imaging technologies, are found in the literature.[28, 29] Consequently, radiation protection during CT examinations is significantly important, irrespective of the amount of radiation dose received.

V 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) Mean ± SD (Min–Max)	DLP (mGy*cm) Mean ± SD (Min–Max)	Effective dose (mSv) Mean ± SD (Min–Max)	Colon dose (mGy) Mean ± SD (Min–Max)	Stomach dose (mGy) Mean ± SD (Min–Max)	Prostate/Uterus dose (mGy) 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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Hussein ALMASRI

Hussein ALMASRI received a PhD in Medicine, Radiology from the University of the Ryukyus, Okinawa, Japan in 2014. He has been working as Head of Medical Imaging Department, Al-Quds University, Jerusalem, Palestine. In 2016, he was an international invited speaker at the JSMP 112. The main field of research is medical imaging and radiation dosimetry; in particular, radiation dose assessment in medical diagnostic and therapeutic applications.

Wala INAYYEM

Wala INAYYEM received an MSc in Public Health from Al-Quds University, Jerusalem, Palestine in 2015. She has been working as a radiographer at the Ministry of Health since 2016. The main field of research is radiation dose assessment in medical diagnostic applications.