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Assessment of patient radiation dose in dual-phase abdominopelvic computed tomography

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► *Short report*

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ABSTRACT

***Background*:** Computed tomography (CT) is a highly effective imaging technique for abdominopelvic pathologies. Nonetheless, radiation concerns arise due to patients receiving a significant effective dose (ED). Thus, patient dose evaluation is critical to ensure that benefits compensate for the projected cancer risk. The current study aimed to assess abdominopelvic CT radiation exposure. ***Material and Methods*:** A cross-sectional analytical design was conducted for 130 abdominopelvic CT procedures. The WAZA-ARI version 2 CT dosimetry system, which is web-based, open Monte Carlo simulation software for CT dose computations was used to calculate organ doses. Lifetime attributable risk (LAR) of cancer induction was calculated for dual-phase abdominopelvic CT through the website "Xrayrisk.com". ***Results*:** Results revealed that the mean ED was slightly lower in females compared to males (13.9±2.9 mSv vs. 15.5±2.7 mSv). The mean EDs for male patients in the arterial and venous phases were 6.2±1.08 mSv and 9.3±1.62, respectively, while the corresponding mean EDs for female patients were 5.56±1.16 mSv and 8.34±1.74. The highest organ equivalent doses for both genders and among all exams were gonads (males 32.55, females 28.76 mSv); small intestine (males 30.26, females 26.66 mSv); colon (males 29.79, females 26.33 mSv), and stomach (males 28.55, females 25.23 mSv). ***Conclusion*:** Variations among organ doses and assumptions regarding negligible risk of malignancy inform current hospital policy. Our findings suggest that achieving the balance between diagnostic benefits and radiation risk requires careful attention.

INTRODUCTION

CT was first introduced in the 1970s and has since evolved into a global imaging modality. Advanced technical options have enabled the application of CT for diagnoses of abdominopelvic section pathologies [1]. CT image quality and speed have improved, as has the technique's robustness and utility. As a result, clinical use of CT has expanded. As a consequence, CT accounts for more than two-thirds of all medical radiation. Seventy five percent of CT scans are performed in hospitals, and 47% of CT examinations are abdominopelvic CT scans [2].

The capability to capture images within a short scanning time increased significantly the number of CT tests performed in clinical settings. As a result, the radiation dosages received by patient populations have grown, posing a public health risk. CT examinations are the most significant source of radiation exposure and effective doses associated with medical examinations [3].

Dual-phase CT of the abdomen-pelvis is one of the leading diagnostic protocols to improve the detection, characterization and localization of several abnormalities such as enlarged lymph nodes, abdominal tumors, fluid collections, air collections outside the gastrointestinal tract, stones or calcifications within the abdominal organs, and bowel obstruction.

Here we investigate patient doses associated with dual-phase abdominopelvic CT procedures. A rise in the frequency of CT examinations has been observed in the Gaza Strip, making CT one of the most significant medical radiation sources, with a six-fold increase in the annual effective dosage from medical operations. The current study aims to analyze abdominopelvic CT and patient radiation dosage at Al-Shifa Complex Hospital in Gaza Strip, Palestine.

MATERIALS AND METHODS

Patient selection

The current study was an analytical cross-sectional design conducted between March and June 2021. We reviewed 130 abdominopelvic CT procedures via patients' medical records and the picture archiving and communication system (PACS). All of the included CT procedures were performed with a similar protocol according to the guidelines of Al-Shifa Complex Hospital in Gaza Strip-Palestine. Ethical approval was obtained from the Ministry of

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Health and from Al-Azhar University-Gaza.

Abdominopelvic CT acquisition parameters

All abdominopelvic CT examinations were performed using the 128-slice Philips Ingenuity. The parameters for the acquisition were a gantry rotation time of 0.5 s, tube kilovoltage 120 kVp and restricted collimator of 128 × 0.625 mm.

The following parameters were recorded for each patient; the tube current (mA), pitch, acquisition time, CT dose index-volume (CTDIvol), weighted CTDI (CTDIw) and dose-length product (DLP). The automatic tube current modulation (ATCM) was used with all patients to adjust the mA corresponding to the patient's size and body-area-dependent attenuation to accomplish optimal image quality. Finally, all patients included in this study were exposed to radiation at both arterial and venous phases.

Statistical analysis

Data were analyzed using IBM SPSS version 25. The quantitative variables were expressed as mean ± standard deviation.

We estimated the organ doses based on WAZA-ARI version 2 CT dosimetry system, a website-based Monte Carlo simulation for CT organ dose estimation [4]. WAZA-ARI v2 was implemented using the recorded values of weighting schemes obtained from the ICRP-103 [5].

Estimates of lifetime attributable risk of cancer

The lifetime attributable risk (LAR) of cancer prediction for the abdominopelvic CT scans was calculated using the online software "X-rayrisk.com", an educational site that contains a web-based calculator for LAR estimation for various body regions based on age, gender, and average dose for a given patient. The additional cancer risk above and beyond the baseline cancer risk is defined as the LAR of cancer incidence and mortality.

RESULTS

Demographic characteristics

The gender distribution was 62 (47.7%) male and 68 (52.3%) female. Study subjects' age ranged from 18 to 71 years (male: 54.3±7.56, female: 52.27±6.43). About two-two-thirds of participants were classified as obese, with BMIs greater than 30.

Abdominopelvic CT acquisition parameters

Table 1 shows the abdominopelvic CT acquisition parameters for male and female study participants. The mean mA for males was greater than it was for females, 266.7±21.2 and 234.9±19.6, respectively. Pitch was approximately equal for both males and females, ranging from 0.8 to 1.2. The mean acquisition times ranged from 19.8 seconds to 20.6 seconds for females and males, respectively. The EDs for males ranged from 13.1 mSv to 16.2 mSv with a mean of 15.5±2.7 mSv, while the EDs for females ranged from 12.6 mSv to 14.9 mSv with a mean of 13.9±2.9 mSv.

Table 1. Image acquisition parameters.

Parameters	Gender	N	Minimum	Maximum	Mean±Std. Deviation
Tube current (mA)	Male	62	232	306	266.7±21.2
	Female	68	221	288	234.9±19.6
Pitch	Male	62	0.8	1.1	0.9±0.21
	Female	68	0.8	1.2	1±0.26
Acquisition Time	Male	62	19.6	22.5	20.6±0.54
	Female	68	18.1	21.2	19.8±0.60
CTDIw	Male	62	6.5	11.2	9.6±1.1
	Female	68	5.9	10.6	8.3±0.9
CTDIvol (mGy)	Male	62	27.6	48.2	40. 9±5.2
	Female	68	26.2	46.8	38.7±4.3
DLP (mGy*cm)	Male	62	875	1078	1032.2±126.5
	Female	68	840	993	926.4±101.2
Effective Dose (mSv)	Male	62	13.1	16.2	15.5±2.7
	Female	68	12.6	14.9	13.9±2.9

Comparison between the arterial and venous phase parameters

The mean EDs for male patients in the arterial and venous phases was 6.2±1.08 mSv and 9.3±1.62, respectively, while the mean EDs for female patients in the arterial and venous phases was 5.56±1.16 mSv and 8.34±1.74, respectively, as shown in table 2.

Table 2. Comparison between the arterial and venous phase parameters.

Parameters	Gender	Arterial Phase		Venous Phase	
		(Min-Max)	Mean ± SD	(Min-Max)	Mean ± SD
DLP (mGy*cm)	Male	350-431.2	412.9±50.6	525-646.8	619.3±75.9
	Female	336-397.2	370.6±40.5	504-595.8	555.8±60.7
Effective Dose (mSv)	Male	5.25-6.48	6.2±1.08	7.86-9.72	9.3±1.62
	Female	5.04-5.96	5.56±1.16	7.56-8.94	8.34±1.74

Effective and organ dose estimations during the dual abdomen CT procedure

The gonads (males 32.55, females 28.76 mSv) and small intestine (males 30.26, females 26.66 mSv) received the highest doses. These were followed by the colon (males 29.79, females 26.33 mSv), stomach (males 28.55, females 25.23 mSv), kidney, pancreas, gall bladder, and spleen, as shown in table 3.

DISCUSSION

CT provides a high level of detail and enables visualization of organs, arteries, muscle, and bone simultaneously. Abdominopelvic CT improves emergency physician diagnostic predictability, minimizes the need for emergency surgery from 13% to 5%, and prevents up to 24% of scheduled hospital admissions [6]. Despite these benefits, there is growing concern that CT is being overused, thereby increasing ionizing radiation exposure and increasing cancer risk [7].

The estimated EDs reported here are inconsistent

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with some previously published values. The ED estimated for the current dual-phase protocol was 15.5±2.7 mSv for male patients, exceeding the average dose of 10–13.29 mSv for a standard abdominopelvic CT reported by Deevband *et al.* [8]. The ED for female patients was lower than for males and close to the upper normal limit according to American Association of Physicists in Medicine (AAPM) Report no. 96, with values between 8 and 14 mSv [9].

Table 3. Effective and organ doses estimations during the dual abdomen CT procedure.

Organ / Tissue	Males	Females
	Dose (mGy)	**Dose (mGy)**
Gonad	32.55 ±2.05	28.76±2.04
Prostate / uterus	23.25±2.04	20.47±2.05
Urinary bladder	28.28±2.12	24.81±2.01
Colon	29.79±3.01	26.33±3.03
Small intestine	30.26±3.04	26.66±3.03
Kidney	27.61± 2.02	24.32± 1.63
Pancreas	27.03± 1.88	23.80± 1.56
Gall bladder	27.16± 1.91	23.92± 1.23
Stomach	28.55± 2.01	25.23± 1.99
Spleen	27.03± 1.10	23.81± 1.01
Adrenals	21.56± 0.97	19.08± 0.99
Liver	24.68± 2.11	21.72± 1.12
Heart	3.83± 0.45	3.37± 0.25
Lungs	5.37± 0.69	4.73± 0.65
Breast	0.70± 0.05	0.61± 0.08
Esophagus	6.12± 1.05	5.34± 1.09
Thymus	0.83± 0.03	0.82± 0.03
Thyroid	0.29± 0.02	0.26± 0.02
Salivary glands	0.06± 0.01	0.05± 0.01
Oral cavity	0.05± 0.01	0.04± 0.01
Out of Thorax	0.01± 0.001	0.01± 0.001
Lens	0.01± 0.001	0.01± 0.001
Brain	0.01± 0.001	0.01± 0.001
Lymphaden	15.08± 2.05	13.24± 2.95
Muscle	9.44± 0.001	8.31± 0.001
Skin	7.41± 0.81	6.52± 0.78
Bone	16.31± 1.05	14.37± 1.08
Active marrow	10.41± 0.94	9.17± 0.91
Effective Dose (mSv)	15.5± 2.43	13.9± 2.22
Life Time Attributed Risk	1 in 1436	1 in 1150

Patient EDs during CT abdominopelvic colonography ranges from 2.3 to 9.8 mSv per procedure [10]. The extensive variation suggests that patients may sometimes be exposed to unnecessary radiation risk. A wide variation in patient doses was reported in previous studies [11]. Most of the dose variation is due to differences in the implementation of dual-phase protocols, increasing scanning regions, or higher mA and pitch settings [12]. Osei and Darko reported that effective doses obtained from abdominopelvic CT examinations ranged between 5.4 and 19.8 mSv [13].

Automatic tube current modulation (ATCM) enables the capture of high-quality images with minimal radiation dose. When compared to fixed tube current approaches, ATCM automatically adjusts the mA as the patient's attenuation varies to achieve optimal image quality while minimizing radiation exposure [14].

The tube voltage is constant (120 kVp) in both arterial and venous phases, and EDs in the arterial and venous phases account for 40% and 60% of the total ED, respectively. In this regard, it is worth noting that using lower tube voltage can minimize radiation dose by up to 57 percent. Also, the reduction of tube voltage from 120 kV to 90 kV can reduce the amount of contrast material by at least 20% without degradation in image quality [15]. Studies reported that the ED were 15.2 mSv (arterial phase of 5.5 mSv and portal phase of 9.7 mSv) [16] and 12.5 mSv (3.9 mSv and 8.6 mSv) respectively [17].

The ICRP has established that the sensitivity of cells and tissues to the hazards of ionizing radiation is affected by age and by biological and physical parameters [18]. The most radiosensitive tissues include the lung, breast, and stomach, and active bone marrow, while the residual tissues have a wide range of sensitivities [5]. During CT exams, these organs get a large amount of radiation, which is linked to a non-negligible risk of cancer [19].

In the current study of radiation dose to the abdomen during dual-phase CT, we considered the effect of obesity. It has been established that utilizing a pitch factor of 0.8 in abdominal CT produces a dose increase in obese individuals relative to a pitch of 1 in non-obese patients. However, because ATCM was activated in our research protocol, the scanner tube output was automatically modified based on the size and shape of the imaged object. Nevertheless, the mean values of CTDIvol and DLP were significantly increased in the group with a higher BMI.

Regarding the LAR, our results showed greater values in females compared to males (1150 female vs. 1: 1436 male). The current readings are in the low cancer risk incidence, which is in the range of 1 in 10,000 to 1 in 1,000. So, comparing these LAR for the current sample size, it indicates that the patients were exposed at an acceptable risk [20].

An abdominal dual phase-protocol is often performed on patients who may be subject to repeat radiation exposures, contributing to additional cancer induction probability .With the current effective dose value, the additional expected cancer risk is of significant concern. Thus, careful justification and optimization of abdominal procedures are recommended. Patient dose reduction can be achieved by selecting optimum exposure parameters and the use of ATCM by well-trained technologists.

The current study provided a rigorous assessment of patient dose during abdominal CT at Al-Shifa Hospital Gaza Strip-Palestine. Study limitations include the sample size and multi-center study access difficulties at a national level needed to derive the national diagnostic reference level (DRL) for patient dose optimization.

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CONCLUSION

Increased efforts to educate physicians and improved radiation protocols to empower CT technicians to select the lowest-dose scanning techniques without sacrificing resolution are among the policies necessary to reduce the risks associated with CT imaging.

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