Radiation Doses to the Uterus and Ovaries in Abdominopelvic Computed Tomography in a Nigerian Tertiary Hospital

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ABSTRACT

Background: Computed tomography (CT) has remained an important tool in medical diagnosis. However the radiation dose imparted to patients, especially to radiosensitive organs during a CT scan, continues to raise concern. Our aim was to determine the radiation dose to the ovary and the uterus during routine abdomen/pelvis CT examinations at the University College Hospital, Ibadan, Nigeria using appropriate dose computational methods. **Materials and Methods:** Technical factors and parameters were obtained for three groups of 60 randomly selected patients who had abdominal CT examinations using three machines, namely; the CT/e, BrightSpeed S and Toshiba Aquilion 64. The scanning parameters were used to estimate the patient organ doses using measurements of CT dose indexes and organ doses obtained with the aid of the ImPACT CT Dosimetry Calculator SpreadSheet based on National Radiological Protection Board conversion factors. **Results:** The mean total organ dose from the CT/e machine to the ovary was 11.15 ±2.48 (mGy) and to the uterus was 12.10 ±2.57 (mGy), and the mean total organ dose from the BrightSpeed S machine to the ovary was 39.2 ± 22.66 (mGy) and to the uterus was 43.05 ±24.88 (mGy), while the mean total organ dose from the Toshiba Aquilion 64 to the ovary was 33.07 ±16.86 (mGy) and to the uterus was 33.85 ±18.58 (mGy). These values were mostly comparable to but slightly higher than values of similar organ doses reported in the literature for Tanzania, the United Kingdom, Germany, and Japan. The doses to the ovary and uterus obtained varied from other international surveys by 3.8–12.9 mGy and 3.17–15.07 mGy, respectively, representing a 25–50% dose increase. **Conclusion:** The organ doses to the ovary and the uterus at our facility are higher than those obtainable in other countries; however, this could be substantially minimized through optimization of CT scanning protocols.

Key words: Computed tomography; patient organ doses; ovary and uterus

Introduction

The clinical significance of computed tomography (CT) in modern medicine cannot be over-emphasized, as it is has become a one stop shop for medical imaging applications and procedures. Its increasing use despite the possible adverse health effects of radiation has prompted the development of many CT dose reducing software and protocols.[1,2]

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Although CT represents only 5% of the total number of medical X-ray procedures worldwide, it contributes about 34% of the annual collective dose from all medical X-ray examinations to the population.[3]

In the United States, it was estimated that CT scanning accounts for about 10% of all radiological examinations and about two-thirds (>60%) of the radiation doses to patients.[4]

Increased CT use also portends an increased risk of radiation effects such as cancer induction.[5]

At the University College Hospital (UCH), Ibadan, Nigeria (reputed as the largest tertiary health institution in the country) where this study was conducted, CT examinations have also witnessed a tremendously high increase of up to 85% since its introduction in 1988.

By its nature, CT involves larger radiation doses than the more common, conventional X-ray imaging procedures. It is, therefore, important to determine the radiation dose to nonsuperficial radiosensitive organs such as the ovaries lungs and kidneys which are irradiated during radiological procedures.[6] This would provide a basis for the formulation of radiation protection and safety measures to limit radiation doses while achieving diagnostic results. It may also serve as a component of population surveys to establish a national diagnostic reference levels.

Materials and Methods

The scanning parameters of sixty female patients, who had abdominopelvic CT examinations at the UCH, Ibadan between July, 2008 and June, 2012 were evaluated. These parameters included, machine type, patient's age, tube current (mA), collimation, rotation or exposure time, X-ray tube kilovoltage (kVp), CT dose indexes$_{vol}$ (CTDI$_{vol}$), and dose-length product (DLP). The data were obtained from the three different CT scanners used in the hospital, namely: GE BrightSpeed S, Toshiba Aquilion 64 and GE CT/e.

Displayed CTDI$_{vol}$ and DLP were extracted from the BrightSpeed S and the Toshiba Aquilion 64 machines, the GE CT/e scanner did not have such facility.

The DICOM images of the patients were retrieved and viewed on a clear canvas standalone viewing workstation. Thereafter, the scanning parameter s used for each patient were entered into the ImPACTScan CT Dosimetry Calculator Spreadsheet version 1.0.4 and analyzed. This dosimetry spreadsheet is a tool for calculating patient organ and effective doses from CT scanner examinations. It makes use of the National Radiological Protection Board Monte Carlo dose data sets produced in the report SR250.[7]

SR 250 provides normalized organ dose data for irradiation of a mathematical phantom as depicted in Figure 1 by a range of CT scanners. ImPACTscan CT Dosimetry Calculator Spreadsheet version 1.0.4 has GE Prospeed, GE CT/i, and Toshiba 16 which belong to the same dose geometric subgroup as our scanners and were used to represent the GE BrightSpeed, GE CT/e and Toshiba Aquilon-64, respectively, due to their similar scan and dose distribution geometry.[7]

The technical specifications and comparisons for these scanners are shown in Table 1.

For this study, the complete series of an examination were used in dose calculations which often include a precontrast, contrast, and delayed venous scans. Once the technical parameters of machine type, such as: kVp, tube milliampere, exposure time (s), and pitch were entered into the spreadsheet as shown in Figure 2, the effective dose and organ doses are automatically calculated. The estimated organ doses to the uterus and ovaries for each scan are obtained and summed up to obtain the complete organ dose. The ranges of scanning parameters used for the three machines are stated in Table 2.

When the model of the CT scanner does not appear in the spreadsheet, the estimated organ or effective dose may be determined by using a known scanner with similar dose geometry or it may be calculated manually using the Deak *et al*. method[8] where conversion factors are already predetermined in a table with machine parameters and using ICRP Publication 60 or ICRP Publication 103. The selected appropriate conversion factor is then multiplied by the DLP obtained from the specified scanner. The conversion factors from DLP to effective dose as a function of voltage, region and age for both ICRP 60 and ICRP 103 publication recommendations are provided in a table format that can be readily used once the DLP is known.

We however did not use the Deak *et al*. method[8] in this study for any of our calculations.

Results

For the abdomen/pelvis CT scans carried out in UCH, there were no standard tube current settings. The settings were varied based on estimated patient weight and desired image quality. The technologist occasionally used automatic

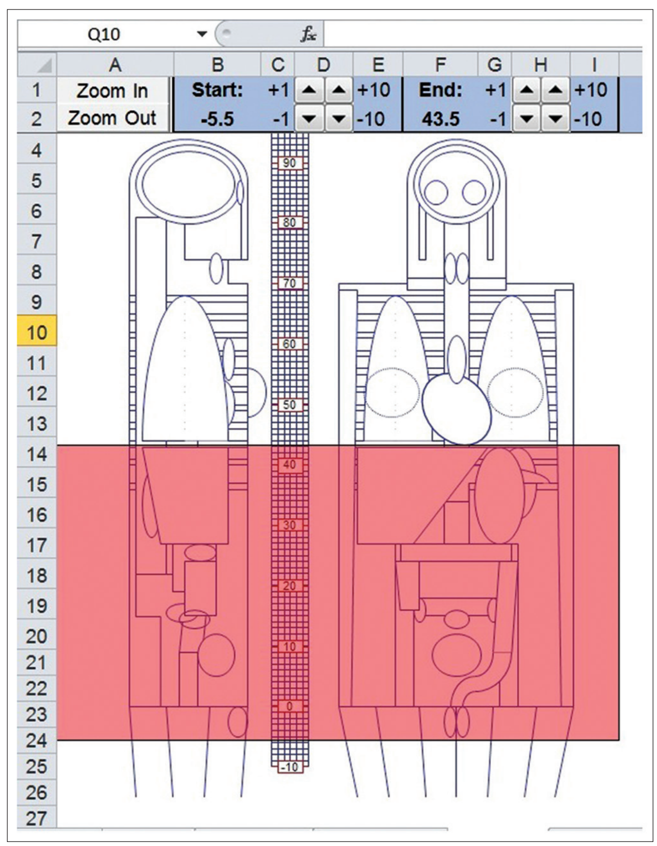
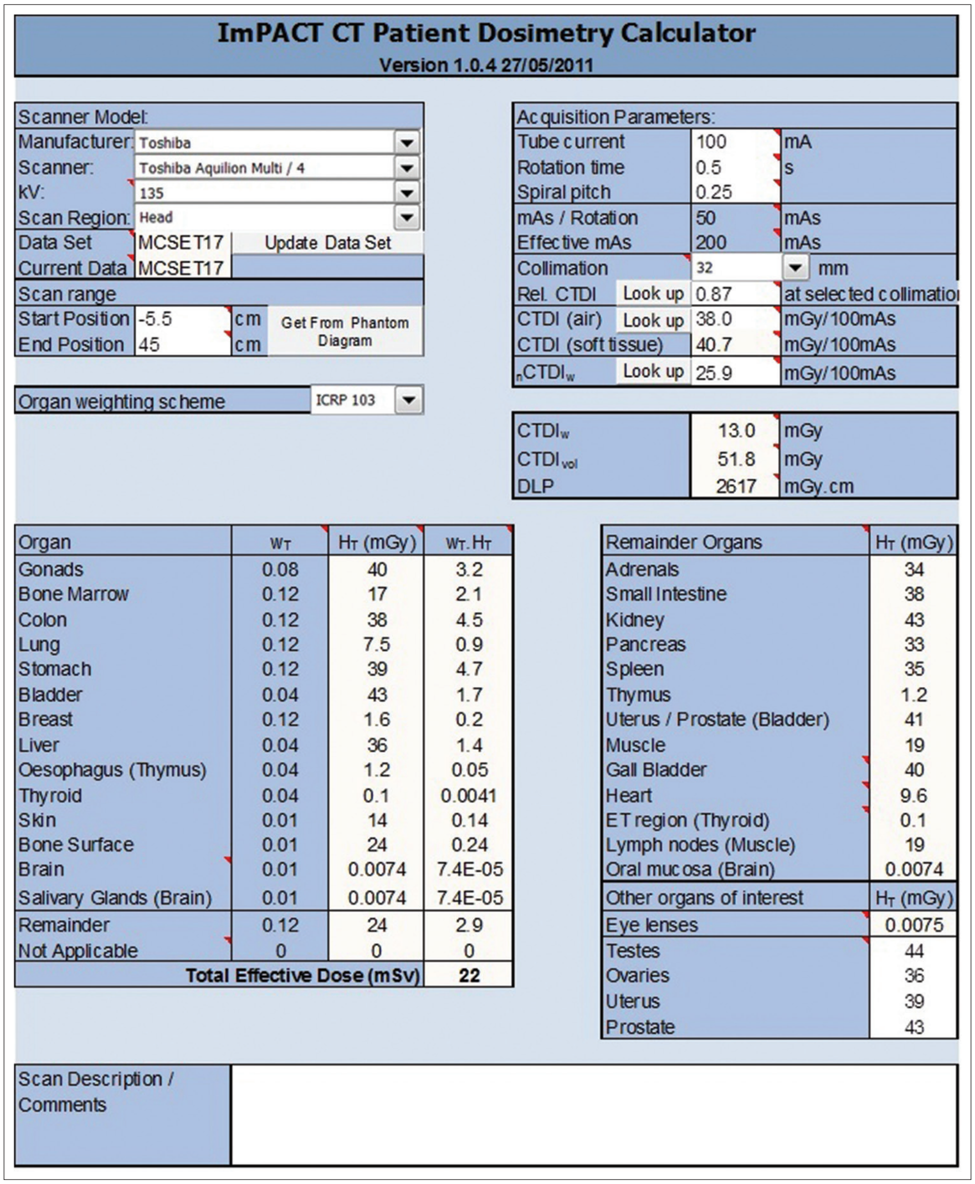


Figure 1: Mathematical phantom used with impact software to compute patient doses at computed tomography



ImPACT CT Patient Dosimetry Calculator

Version 1.0.4 27/05/2011

Scanner Model:		
Manufacturer:	Toshiba	
Scanner:	Toshiba Aquilion Multi / 4	
kV:	135	
Scan Region:	Head	
Data Set	MCSET17	Update Data Set
Current Data	MCSET17	
Scan range		
Start Position	-5.5 cm	Get From Phantom Diagram
End Position	45 cm	
Organ weighting scheme	ICRP 103	

Acquisition Parameters:			
Tube current		100	mA
Rotation time		0.5	s
Spiral pitch		0.25	
mAs / Rotation		50	mAs
Effective mAs		200	mAs
Collimation		32	mm
Rel. CTDI	Look up	0.87	at selected collimation
CTDI (air)	Look up	38.0	mGy/100mAs
CTDI (soft tissue)		40.7	mGy/100mAs
$_nCTDI_w$	Look up	25.9	mGy/100mAs

$CTDI_w$	13.0	mGy
$CTDI_{vol}$	51.8	mGy
DLP	2617	mGy.cm

Organ	W_T	H_T (mGy)	$W_T.H_T$
Gonads	0.08	40	3.2
Bone Marrow	0.12	17	2.1
Colon	0.12	38	4.5
Lung	0.12	7.5	0.9
Stomach	0.12	39	4.7
Bladder	0.04	43	1.7
Breast	0.12	1.6	0.2
Liver	0.04	36	1.4
Oesophagus (Thymus)	0.04	1.2	0.05
Thyroid	0.04	0.1	0.0041
Skin	0.01	14	0.14
Bone Surface	0.01	24	0.24
Brain	0.01	0.0074	7.4E-05
Salivary Glands (Brain)	0.01	0.0074	7.4E-05
Remainder	0.12	24	2.9
Not Applicable	0	0	0
		Total Effective Dose (mSv)	22

Remainder Organs	H_T (mGy)
Adrenals	34
Small Intestine	38
Kidney	43
Pancreas	33
Spleen	35
Thymus	1.2
Uterus / Prostate (Bladder)	41
Muscle	19
Gall Bladder	40
Heart	9.6
ET region (Thyroid)	0.1
Lymph nodes (Muscle)	19
Oral mucosa (Brain)	0.0074
Other organs of interest	**H_T (mGy)**
Eye lenses	0.0075
Testes	44
Ovaries	36
Uterus	39
Prostate	43

Scan Description / Comments

Figure 2: ImPACTscan Dosimetry Calculator Spreadsheet showing input data from the Toshiba scanner and diving the effective dose and dose distribution of a single scan

Table 1: Technical specifications and comparisons the scanners used

Technical specification	GE CT/e	GE Brightspeed S	Toshiba Aquillion 64
Scanner type	3rd generation	3rd generation	3rd generation
Aperture (cm)	70	70	72
Slip ring for data transmission	Contact	Contact	RF
Tilt for helical scanning	No	No	±30
kV settings	80, 100, 120	80, 100, 120, 140	80, 100, 120, 135
mA range	10-500	10-600	10-700 (10-600 option)
Maximum anode cooling rate (kHU/min)	Unavailable	2100	1386
Rotation time for sequential scanning (s)	1.0	0.8, 1.0	0.35, 0.4, 0.5, 0.75, 1.0, 1.5 (standard)
Thinnest collimation (mm)	1.0	0.625	0.5

CT – Computed tomography

dose-reduction system (known as auto mA), which varied the tube current based on the patient size.

Table 2 summarizes the most common settings used for the abdomen/pelvis CT examinations in UCH, Ibadan.

All routine abdomen/pelvis CT were performed using 120 kVp, and these were done for either two- or three-phase examinations and all studies were routinely extended to the pelvis. The total DLP recorded represents the complete study including both precontrast and postcontrast phases.

The effective dose and specific organ doses for each machine were determined with the aid of the ImPACTScan Patient Dosimetry Calculator.

Table 3 shows the comparison of mean total organ doses for a complete scan series to the uterus and the ovaries from the three CT scanners used in this study.

It is pertinent to compare the values obtained from this study with values obtained from earlier surveys.

Table 4 shows the comparison of the values for the organ doses to the ovaries and the uterus obtained from this study with those obtained from similar studies from other countries.

Discussion

The radiation dose, a patient receives, could be dependent on many factors and understanding these factors and the interplay of their relationships is very important in radiation protection as well as in developing strategies of minimizing dose.

In a survey carried out in Tanzania,[9] the mean organ doses to the ovaries and the uterus were 24 ± 17.1 and 26.5 ± 18.6, respectively, and when compared to other studies, it was observed that variations in the results were attributed to variation of clinical indications among patients, use of contrast, and number of slices used depending on patient size.[7]

Depending on the scanner type, and machine specifications, the absorbed dose during an abdomen scan may vary by a factor of 10–40. And when dose ranges from only a single CT machine model is considered, the dose may still vary by 5–20 times.[10-12]

This is also reflected in the reference-dose levels for CT from the UK CT survey of the early 1990s, which is commonly quoted and even adopted by the European Union.[13]

The values reported from the present study for the organ doses were mostly compared with those obtained from similar studies in Tanzania, the United Kingdom, Germany, and Japan. However, in both results reported from Tanzania and the UK, the variation of the mean organ doses appear to vary by a factor of between 2 and 4, respectively, while the variation between this study and those from Germany and Japan varied by a factor as high as 14. This higher organ doses observed in this study relative to those reported from Japan and Germany might be attributed to the different methods used for estimation of organ doses, for instance, in Japan, the authors used thermoluminescent dosimeters in a female Rando Alderson phantom.[14]

Furthermore, it is possible that the tube current values were significantly smaller or automatic mA regulation was used in the studies carried out in Germany and Japan which would also explain the smaller values in organ doses.

Our study was retrospective investigative observation which may be used for optimization and development of dose reference levels after making comparisons with similar studies.

The results show a need to optimize the protocols for abdomen/pelvic examinations in this large Nigerian tertiary institution with the potential of influencing practices in other peripheral and future hospitals and diagnostic facilities. The use of radiation for medical imaging and diagnoses must constantly be surveyed in order to help reduce the possible deleterious effects radiation dose especially during exposure of highly radiosensitive areas such as the ovary and uterus.

Table 2: Commonly used parameters for abdomen/pelvis CT study in UCH

Abdomen/pelvis	Range	Most common
Slice thickness (mm)	0.675-7	5
Tube potential (kVp)	120-140	120
Pitch	0.75-1.5	1.35

CT – Computed tomography; UCH – University College Hospital; kVp – Kilovoltage

Table 3: Comparison of the mean total organ doses (mGy) for a complete scan series to the uterus and the ovary from the machines

CT scanner	Ovary (mGy)	Uterus (mGy)
GE CT/e	11.15±2.48	12.10±2.57
GE brightspeed S	39.20±22.66	43.05±24.88
Toshiba aquilion 64	33.07±16.86	33.85±18.58

CT – Computed tomography

Table 4: Comparison of mean organ doses in this study with other studies (mGy)

CT exam	Selected organ	This study*	Tanzania[8]	UK[8]	Germany[8]	Japan[8]
Abdomen-pelvis	Ovary	27.8±14.0	24±17.1	22.7	14.9	15.1
	Uterus	29.6±15.3	26.5±18.6	25.5	14.6	-

*The values used here are the mean of the mean total organ doses for the three machines. CT – Computed tomography

Therefore, procedural steps should be taken to reduce the patient doses by some percentage while maintaining good and diagnostic image quality.

Limitations

Phantom measurements were not performed to further substantiate and provide complimentary evidence of the observed increase in the calculated patient doses for the three CT scan machines. We could not overcome this limitation due to lack of the appropriate pencil ionization chamber with a calibrated dosimeter at the index institution at the time of writing. This, however, could form the basis for additional research in this region.

Conclusion

The patient organ doses to the ovary and the uterus in our hospital are relatively higher than levels obtainable in other countries. However, this could be substantially minimized through optimization of CT scanning protocols and appropriate selection of scanning parameters.

CT manufacturers should continue to focus on improving CT technology with an aim at improving image quality using the least dose.

Local and national CT radiation surveys would always be indispensable in achieving acceptable and best radiation practice in any environment.

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