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Research Paper

Effect of Practice of Transferring Patients Scanning Protocols between Computed Tomography Scanners

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Abstract

Radiation protection of patients, as they undergo computed tomography (CT) diagnostic examinations, should be considered to ensure their safety. One way to achieve this is to guide against unhealthy 'migration' of scanning protocols between CT scanners, as reported by the International Committee for Radiation Protection. The aim of this study was to determine the effect of migrating CT scanning protocols between CT scanners by estimating and comparing effective doses of selected examinations across eight CT facilities. Eight CT units (GE, Hilight, Hispeed.CT/I (No SmB) (GHH), Toshiba Aquilion 16 (T16), Siemens Sensation 4 (SS4), Picker UltraZ (PUZ), Philip Brilliance 64/40 (PB64), Mx8000IDT/Brilliance 16 (MxIDT), Philips AV. LX, SR7000 (PAV) and GE Pace, Sytec (PS)) were selected. A CT patient dosimetry calculator, CT-RADOSE was used to determine effective dose to the head, chest, abdominal and pelvic regions from CT scanning parameters for 36 patients. Data analysis was done using Microsoft excel package. The estimated effective dose values ranged from 0.32±0.12-0.82±0.31 and 0.89±0.22-2.21±0.55 mSv at 80 kVp and 120 kVp respectively for head CT, 1.76±0.57-3.83±1.24, 4.70±1.12-10.03±2.51 and 5.95±1.21-13.33±3.36 mSv at 80, 120 and 140 kVp respectively for chest CT, 9.70±2.53-14.21±3.55, 14.79±3.15-21.33±4.54 mSv at 80 kVp, 120 kVp and 140 kVp respectively for abdominal CT and 3.43±1.11-4.34±1.39, 8.37±2.18-10.77±2.69 and 12.11±2.76-15.12±3.29 mSv at 80 kVp, 120 kVp and 140 kVp respectively for pelvic CT. Differences in the calculated effective dose values between the eight CT scanners were found to be statistically significant, ($p < 0.05$). Significant differences in the values of effective dose among the eight CT scanners suggest an increased risk of radiation exposure to patients when CT scanning parameters are indiscriminately transferred between CT scanners.

Keywords: Computed tomography; CT parameters' migration; Effective dose; Radiation effects; Technique chart.

Introduction

Computed tomography (CT) is a medical imaging technique which involves the use of ionizing radiation in medicine to obtain detailed internal images of the body for diagnostic purposes. The image produced on film represents the total attenuation of the X-ray beam as it passes through the patient [1]. The use of CT scans has increased immensely over the last two decades all over the world. For instance, an estimated 72 million scans were performed in the United States in 2007 and more than 80 million in 2015 [2]. Another report showed that in the United States of America (USA), there was an estimated 25% increase in the number of CT scans performed in 2016 in comparison with those carried out in 2006 (about 67 million CT scans in 2006 compared to about 84 million in 2016) and an increase in the number of patients who received CT examinations by about 41% between the years 2015–2018 in the European countries [3]. CT scan is applicable in the imaging of different parts of the body. CT scanning of the head, for instance, is typically used to detect infarction, tumours, calcifications, haemorrhage and bone trauma [4]. It is also used in CT-guided stereotactic surgery and radiosurgery for treatment of intracranial tumours. In diagnostic examination of the neck, CT scan is used in the evaluation of thyroid cancer and thyroid abnormalities [5].

In spite of the huge benefits derivable from CT scan, concerns have been raised around the world about the safety of the procedure [6]. Computed tomography is now recognized as a source of potential risk to patients [1, 6, 7]. One of the major concerns is that, of all the various radio-diagnostic techniques, CT contributes the highest radiation dose to patients.

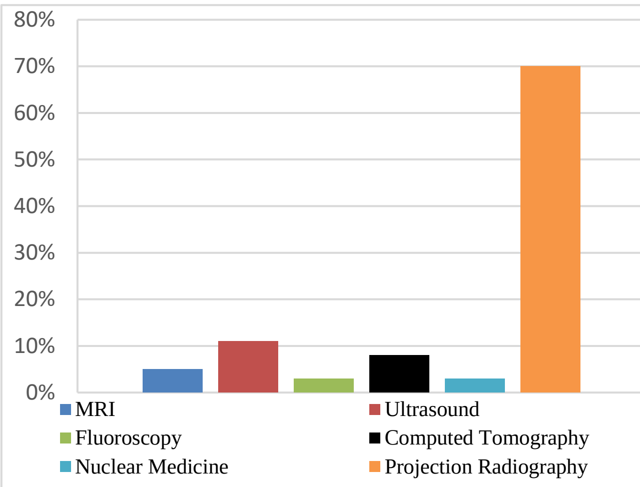

Figure 1. Distribution of various radio-diagnostic imaging examinations [1].

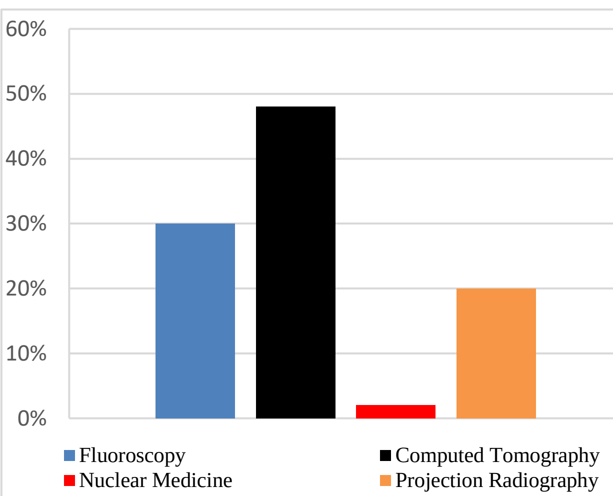

Figure 2. Contribution of individual imaging technique to total patients' radiation exposure [1].

A case in point is the experience in the USA, where, although CT accounts for about 8% of all radio-diagnostic examinations, it contributes approximately 48% of patients' radiation dose (Figures 1 and 2) [1], while in the UK, CT was reported to contribute to 47% of the collective dose from diagnostic radiology, but representing only 9% of all X-ray examinations [8]. Another reason for concern is the potential risk of cancer induction from the use of CT, due to incidence of high radiation dose and low radiation dose [9, 10, 11]. Researchers estimated that at least, 2% of all future cancers in the U.S (about 29000 cases and 15000 deaths each year) are likely to come from CT scan alone [7]. Although, the threat is huge in children [12], older people face the risks, too [2]. Concerted efforts are, therefore, required to protect patients undergoing this imaging technique. These protective measures should aim at constantly assessing radiation doses and risks to patients [8, 10, 13, 14, 15, 16, 17].

A dose parameter that reflects this radiation risk is the effective dose [18]. It is useful in comparing doses from different diagnostic and therapeutic procedures and for comparing the use of similar technologies and procedures in different hospitals and countries as well as comparing risks from different technologies for the same medical examinations [18]. The aim of this study was to estimate and compare the effective doses, to head, chest, abdomen, and pelvis in 36 patients, from 8 different CT scanners, using the same CT scanning protocols.

Materials and Methods

Patients' data and technique chart

Patient exposure parameters and CT technique chart were collected, for 36 pediatric, young adult and adult patients, from six computed tomography centers in four of the South-Western states, Nigeria. These data provided information on the patient's age and weight, while the technique chat included the identity of the 36 patients (patients' identity was presented in numbers to protect the personality of the patients), mass (kg), scanned region, scan pitch, tube current-time product (mAs), scan length (cm) and rotation time (s) (Table 1). Patients 1-9 underwent head CT examination, patients 10-18 underwent chest CT examination, patients 19-27 underwent abdominal CT examination, while patients 28-36 underwent pelvic CT examination. The patients' data and technique chart were used to compute effective dose to anatomic regions head, chest, abdomen, and pelvis of the patients.

Software for computation

All CT effective doses were calculated using CT-RADOSE, a computer program developed from Microsoft Visual Basic 6.0 for calculating CT dose and scanning parameters. The software was designed based on the following research papers; (i) method based on energy imparted during CT procedure [19, 20] (ii) radiation effective doses to patients undergoing abdominal CT examinations [21, 22], (iii) effective doses to patients undergoing thoracic computed tomography examinations [23] and (iv) patient technique factors in head computed tomography [24]. In CT head examination, effective dose was computed at 80 kVp only for seven of the eight CT scanners used in this work. The exception was for Mx8000IDT/Brilliance 16 (MxIDT), due to non-availability of the value of free-in-air CTDI for the scanner at 80 kVp. However, CT head examination effective dose was computed for all the eight CT scanners at 120 kVp. For body CT (abdomen, chest, and pelvis), effective dose was computed at 80 kVp, 120 kVp and 140 kVp for all the eight CT scanners. The only exception was for Toshiba Aquilion 16 (T16), also due to non-availability of the value of free-in-air CTDI for the scanner at 140 kVp. (Table 2).

Equations for computation of effective dose

Equations 1-3 were used by CT-RADOSE to compute the effective dose values in this work. Equation 1 was used to compute effective dose to pediatric patients in abdominal, pelvic and chest CT examinations, equation 2 was used to estimate the effective dose to adult patients in abdominal, pelvic and chest CT examinations and equation 3 estimated effective dose to both pediatric and adult patients in head CT examination.

$$E = \pi \times r^2 \times T \times \rho_w \times D_T \times N \times (E/\mathcal{E})_i \times (M_{Ai}/M_{Pi}) \times nCTDI_{F(siem)} \times mAs \times \frac{\left(\frac{CTDI_W}{CTDI_F}\right)_X}{\left(\frac{CTDI_W}{CTDI_F}\right)_{Siem}} * \qquad (1)$$

$$E = \pi \times r^2 \times T \times \rho_w \times D_T \times N \times (E/\mathcal{E})_i \times (70/M_B) \times nCTDI_{F(siem)} \times mAs \times \frac{\left(\frac{CTDI_W}{CTDI_F}\right)_X}{\left(\frac{CTDI_W}{CTDI_F}\right)_{Siem}} * \qquad (2)$$

$$E = 10^{(3.01 - 2.05(\log_{10}M + 0.461(\log_{10}M)^2)} \times \pi \times r^2 \times T \times nCTDI_{F(siem)} \times D_T \times mAs \times N \times \rho_w \times \frac{\left(\frac{CTDI_W}{CTDI_F}\right)_X}{\left(\frac{CTDI_W}{CTDI_F}\right)_{Siem}} * \qquad (3)$$

The equations consist of essential parameters abbreviated as: E = effective dose; r = radius of the imaged body part; T = beam collimation; ρ_w = density of water; D_T = mean section dose per $nCTDI_F$; N= number of gantry rotations required to cover the imaged anatomy; $(E/\mathcal{E})_i$ = effective dose-to- imparted energy conversion factor for body region i to be scanned [20]; M_B = mass of adult patient (kg); M_{Pi} = direct irradiated mass of the anatomic region to be scanned in a pediatric patient; M_{Ai} = mass of the same anatomic region i in the 70 kg adult phantom as with the pediatric patient [20]; * = conversion factor from Siemens Somatom Sensation 16, used in the research papers upon which the dose calculator is based, to any scanner of interest X; $nCTDI_{F(siemens)}$ = normalized free-in-air computed tomography dose index of Siemens Somatom Sensation 16, expressed in mGy/mAs. It is determined by dividing $CTDI_F$ values by the corresponding tube load mAs; $CTDI_w$ = weighted value of CTDI; $CTDI_F$ = scanner specific CT dose index free-in-air.

Statistical tool used

Analysis of the values of effective dose computed was done using Microsoft Excel Package. Descriptive statistics was used to determine mean effective dose and standard deviation. Independent Sample F-test (one-way analysis of variance, ANOVA) was used to compare our results. $p < 0.05$ was termed to be statistically significant.

Results

Using the patients' exposure data in Table 1, the dose calculator, CT-RADOSE was used to compute effective dose for the 36 subjects included in our work. This calculation was done for the 8 different CT scanners presented in Table 2. The results showed the standard deviations and means of the values of effective dose for each of the CT scanners for the patients involved in each class of scan (head, chest, abdomen, and pelvis) at the various tube potentials of 80 kVp, 120 kVp and 140 kVp. These results are reported in Tables 3 and 4. Comparison of these results was done by statistical analysis and presented in Figures 3-5, while Tables 6 and 7 present values of coefficients of variation among the scanners for each of the patients.

Table 5 shows the p-values of one-way analysis of variation (ANOVA) F-test performed on the values of effective dose in Tables 3-4. All the calculated values showed p-values less than 0.05 ($p < 0.05$), the level of significance. This shows considerable difference in the effective dose output for the 8 CT scanners used in this work and thus their radiation effects.

Table 1. CT Technique Chart for the CT examination of the 36 patients included in this work

Patient's identity	Class of patients	Sex (M/F)	Mass (kg)	Rotation time (s)	Scan length (cm)	Current time product (mAs)	Scanned region	Scan pitch
1	Pediatric	M	3.4	1	5.25	150	Head	1
2	Pediatric	M	10.8	1	11.3	150	Head	1
3	Pediatric	F	19	1	12.6	150	Head	1
4	Young adult	M	45	1	12.6	220	Head	1
5	Young adult	F	50	1	12.6	220	Head	1
6	Young adult	F	55	1	12.6	220	Head	1
7	Adult	M	70	1	13	340	Head	1
8	Adult	F	73	1	13	340	Head	1
9	Adult	F	76	1	13	340	Head	1
10	Pediatric	F	6.93	1	8	100	Chest	1.5
11	Pediatric	M	11	1	14	100	Chest	1.5
12	Pediatric	M	19	1	15	100	Chest	1.5
13	Young adult	F	46	1	26.2	180	Chest	1.5
14	Young adult	F	50	1	25	180	Chest	1.5
15	Young adult	M	55	1	24.3	180	Chest	1.5
16	Adult	M	62.5	1	31.5	220	Chest	1.5
17	Adults	F	65	1	31.5	220	Chest	1.5
18	Adults	F	73	1	31.5	220	Chest	1.5
19	Pediatric	F	4.5	1	7	220	Abdomen	1.5
20	Pediatric	M	15	1	11	220	Abdomen	1.5
21	Pediatric	M	23	1	15	220	Abdomen	1.5
22	Young adult	F	36	1	22	260	Abdomen	1.5
23	Young adult	M	38	1	22	260	Abdomen	1.5
24	Young adult	M	43	1	22	260	Abdomen	1.5
25	Adult	F	61	1	31.5	290	Abdomen	1.5
26	Adult	M	73	1	31.5	290	Abdomen	1.5
27	Adult	F	77	1	31.5	290	Abdomen	1.5
28	Pediatric	F	5	1	6.9	160	Pelvis	1.5
29	Pediatric	F	12	1	10	160	Pelvis	1.5
30	Pediatric	M	15	1	12.82	160	Pelvis	1.5
31	Young adult	M	30	1	18	200	Pelvis	1.5
32	Young adult	F	39	1	19.5	200	Pelvis	1.5
33	Young adult	F	46	1	19.83	200	Pelvis	1.5
34	Adult	M	60	1	25	220	Pelvis	1.5
35	Adult	M	65	1	25	220	Pelvis	1.5
36	Adult	F	72	1	25	220	Pelvis	1.5

Table 2. Free-in-air CTDI values for the eight scanners used in this work [25]

Tube potential	Scanned region	GHH	T16	SS4	PUZ	PB64	PAV	PS	MxIDT
80 kVp	Head	8.5	15.9	12.2	16.5	7.0	4.3	20.1	NA
	Body	8.5	21.9	6.9	17.7	7.0	8.7	19.2	NA
120 kVp	Head	19.3	36.2	27.2	31.4	21.5	19.2	41.6	19.5
	Body	18.8	45.8	18.9	33.6	21.5	19.3	41.0	19.5
140 kVp	Body	25.8	NA	26.4	42.5	31.0	26.0	54.1	28.1

Table 3. Mean values + SD of effective dose for head CT (patients 1-9) and chest CT (patients 10-18) exams at various tube potentials of 40 kVp, 120 kVp and 140 kVp for the eight scanners used in this work.

Scanner	Head		Chest		
	80 kVp	120 kVp	80 kVp	120 kVp	140 kVp
GHH	0.35 ± 0.11	0.91 ± 0.29	1.44 ± 0.43	4.38 ± 1.35	6.69 ± 2.04
T16	0.65 ± 0.21	1.70 ± 0.55	3.92 ± 1.19	10.22 ± 3.15	Nil
SS4	0.67 ± 0.22	1.59 ± 0.51	2.46 ± 0.74	7.14 ± 2.20	7.14 ± 2.20
PUZ	0.48 ± 0.16	1.08 ± 0.35	3.48 ± 1.05	8.16 ± 2.51	11.65 ± 3.56
PB64	0.41 ± 0.14	1.27 ± 0.41	2.19 ± 0.67	7.14 ± 2.20	11.06 ± 3.37
PAV	0.23 ± 0.07	1.11 ± 0.36	2.52 ± 0.77	7.24 ± 1.67	9.10 ± 2.78
MxIDT	Nil	1.12 ± 0.36	Nil	6.27 ± 1.93	9.42 ± 2.88
PS	0.76 ± 0.25	1.81 ± 0.59	3.74 ± 1.14	9.31 ± 2.87	13.65 ± 4.17

Scanners: GHH-GE,Hilight,Hispeed,CT/i(No SmB), **T16**-Toshiba Aquilion 16, **SS4**-Siemens Sensation 4**, PUZ**-Picker UltraZ, **PB64**-Philip Brilliance 64/40, **PAV**-PhilipsAV,LX,SR7000, **MxIDT**-Mx8000IDT/Brilliance- 16, **PS**-GE Pace, Sytec

Table 4. Mean values + SD of effective dose for abdominal CT (patients 19-27) and pelvic CT (28-36) exams for the eight scanners used in this work. The results are shown for tube potentials of 80 kVp, 120 kVp, and 140 kVp.

Scanner	Abdomen			Pelvis		
	80 kVp	120 kVp	140 kVp	80 kVp	120 kVp	140 kVp
GHH	2.44 ± 0.42	6.93 ± 1.04	11.41±1.66	2.01±0.19	5.78±0.57	8.76±0.83
T16	6.56 ± 0.97	16.19±2.43	Nil	5.47±0.52	13.49±1.33	Nil
SS4	4.11 ± 0.61	11.31±1.71	17.94±2.60	3.43±0.33	9.41±0.92	13.8±1.29
PUZ	5.81 ± 0.86	12.90±1.95	19.83±2.89	4.74±0.35	10.50±0.79	14.9±1.11
PB64	3.66 ± 0.54	11.31±1.71	18.87±2.73	3.13±0.33	9.67±1.05	16.46±1.73
PAV	4.21 ± 0.62	9.50 ± 1.89	15.5±2.24	3.51±0.33	7.89±1.10	11.9±1.13
MxIDT	Nil	9.92 ± 1.49	16.03±2.35	Nil	8.27±0.81	12.32±1.14
PS	5.50 ± 0.94	14.72±2.19	23.26±3.37	5.22±0.50	12.27±1.18	17.88±1.69

Scanners: GHH-GE,Hilight,Hispeed,CT/i(No SmB), **T16**-Toshiba Aquilion 16, **SS4**-Siemens Sensation 4**, PUZ**-Picker UltraZ, **PB64**-Philip Brilliance 64/40, **PAV**-PhilipsAV,LX,SR7000, **MxIDT**-Mx8000IDT/Brilliance- 16, **PS**-GE Pace, Sytec

Table 5. F-test (one-way analysis of variance (ANOVA)) p-values for effective dose for the eight CT scanners used in this work.

Tube potential (kVp)	Head	Chest	Abdomen	Pelvis
80	8.20E-08	3.80E-07	3.80E-18	5.60E-28
120	1.10E-04	5.50E-05	2.20E-15	1.20E-24
140	Nil	1.70E-03	8.80E-12	1.60E-20

Table 6. Coefficients of variation (COV) for Head CT (80 and 120 kVps) and Chest CT (80, 120 and 140 kVps).

Patients' identity	Head		Patients' identity	Chest		
	80 kVp	**120 kVp**		**80 kVp**	**120 kVp**	**140 kVp**
1	0.380	0.249	**10**	0.325	0.238	0.255
2	0.390	0.262	**11**	0.324	0.238	0.255
3	0.372	0.251	**12**	0.323	0.238	0.254
4	0.375	0.253	**13**	0.325	0.237	0.253
5	0.377	0.249	**14**	0.324	0.238	0.255
6	0.369	0.239	**15**	0.325	0.238	0.254
7	0.375	0.248	**16**	0.325	0.251	0.252
8	0.374	0.249	**17**	0.325	0.250	0.254
9	0.378	0.249	**18**	0.325	0.251	0.248

Table 7. Coefficients of variation (COV) for Abdominal CT (80 and 120 kVps) and Pelvic CT (80, 120 and 140 kVps).

Patients' identity	Abdomen			Patients' identity	Pelvis		
	80 kVp	120 kVp	140 kVp		80 kVp	120 kVp	140 kVp
19	0.309	0.260	0.214	28	0.325	0.261	0.213
20	0.309	0.259	0.213	29	0.324	0.260	0.227
21	0.308	0.261	0.212	30	0.325	0.259	0.228
22	0.309	0.261	0.214	31	0.316	0.260	0.229
23	0.309	0.261	0.211	32	0.315	0.257	0.232
24	0.308	0.259	0.213	33	0.314	0.258	0.233
25	0.304	0.249	0.213	34	0.320	0.249	0.217
26	0.309	0.250	0.212	35	0.319	0.249	0.218
27	0.309	0.249	0.213	36	0.320	0.248	0.218

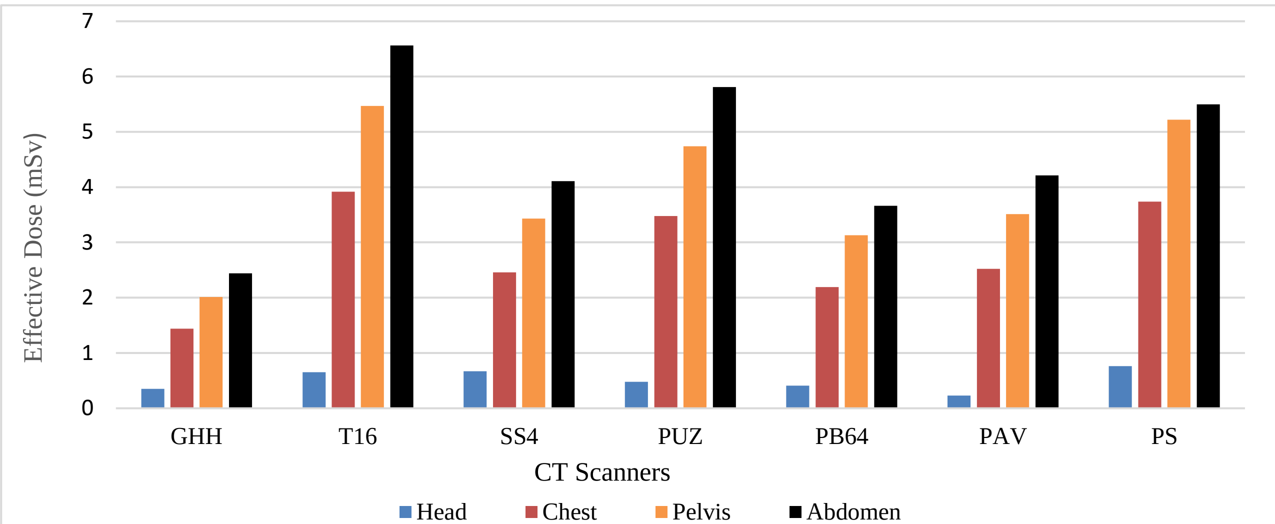

Figure 3. Mean values of effective dose at 80 kVp for head, chest, pelvis and abdominal CT exams for seven of the eight scanners used in this work.

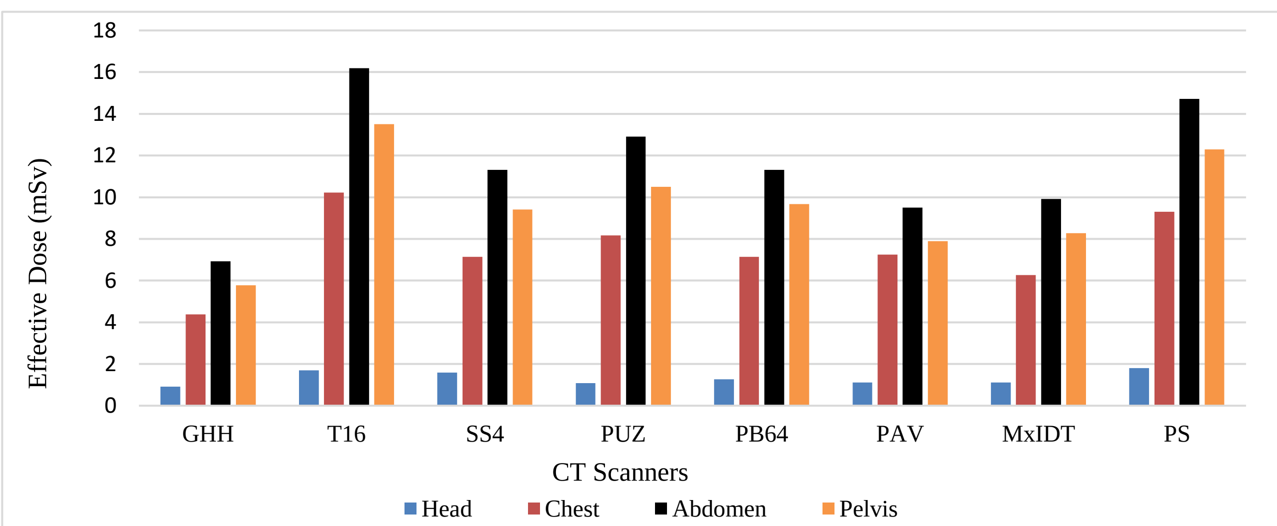

Figure 4. Mean values of effective dose at 120 kVp for head, chest, abdominal and pelvic CT exams for the eight scanners used in this work.

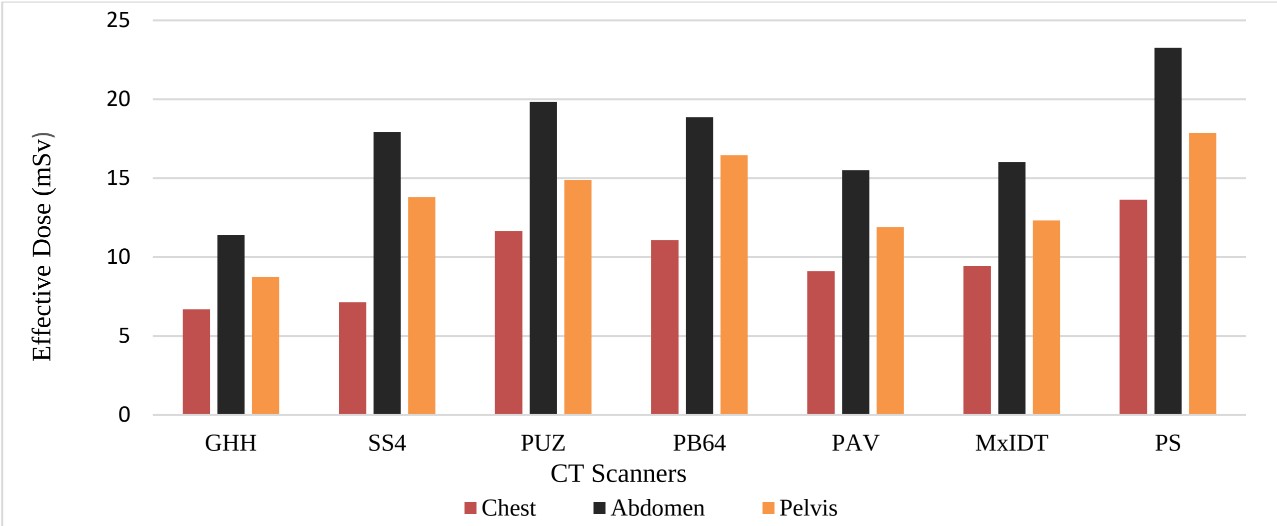

Figure 5. Mean values of effective dose at 140 kVp for chest, abdominal and pelvic CT exams for seven of the eight scanners used in this work.

Discussion

The annals of the International Committee for Radiation Protection (ICRP) reported the case of possibility of transfer or migration of technique factors from one CT scanner to another in diagnostic centres with the capacity to have two or more scanners of different models or from different manufacturers [18]. The results, as presented in Tables 3 and 4, point to the effect of this practice. Using the same technique factors (Table 1), the results of effective dose for head CT examinations, at 80 kVp, showed that GE Pace, Sytec (PS) recorded the highest values for the nine patients 1-9, with mean dose 0.76 mSv (Table 3 & Figure 3), while the lowest mean effective dose value of 0.23 mSv was recorded by Philips AV, LX, SR7000 (PAV). At 120 kVp, the lowest mean effective dose value 0.91 mSv was recorded by GE Hilight, Hispeed, CT/i (No SmB) (GHH) for the nine patients, while GE Pace, Sytec (PS) recorded the highest value of 1.81 mSv (Table 3 & Figure 4). There was no computation of effective dose for head CT at 140 kVp. In the chest CT mode, for patients 10-36, at 80 kVp and 120 kVp, Toshiba Aquilion16 (T16) recorded the highest values of 3.92 mSv (80 kVp) and 10.22 mSv (120 kVp) respectively, while GE Hilight, Hispeed, CT/i (No SmB) (GHH) had the lowest values of 1.44 mSv (80 kVp) and 4.38 mSv (120 kVp) respectively. At 140 kVp, GE Pace, Sytec (PS) had the highest value of 13.65 mSv, while GE Hilight, Hispeed, CT/i (No SmB) (GHH) had the lowest value of 6.69 mSv (Table 3 & Figure 4). Similar trends were observed for abdominal and pelvic CT at both 80 kVp and 120 kVp, with Toshiba Aquilion16 (T16) recording the highest values 6.56 mSv (abdomen, 80 kVp) and 16.19 mSv (abdomen, 120 kVp), 5.47 mSv (pelvis, 80 kVp) and 13.49 mSv (pelvis, 120 kVp), and GE Hilight, Hispeed, CT/i (No SmB) (GHH) having lowest values 2.44 mSv (abdomen, 80 kVp) and 6.93 mSv (abdomen, 120 kVp), 2.01 mSv (pelvis, 80 kVp) and 5.78 mSv (pelvis, 120 kVp) (Table 4 and Figures 3 & 4). At 140 kVp, however, GE Pace, Sytec led with values of 23.26 mSv (abdomen) and 17.88 mSv (pelvis), while GE Hilight, Hispeed, CT/i (No SmB) had the lowest values 11.41 mSv (abdomen) and 8.76 mSv (pelvis) (Table 4 and Figure 5). Tables 6 and 7 also show this effect of scanning protocol migration, in terms of coefficients of variation. For instance, for patient with identity number 1, who presented himself for head CT, the value of the coefficient of variation among the 7 CT scanners at 80 kVp is 0.380, while among the 8 CT scanners at 120 kVp, the value of coefficient of variation is 0.249. This indicates that variation in effective dose among the 7 CT scanners at 80 kVp is about 1.52 times the variation in effective dose among the 8 CT scanners at 120 kVp for patient number 1.

The ICRP warned against this practice of protocol transfer between CT scanners by stating that there are considerable differences between geometries of CT scanners that affect the distance between the focal spot of the X-ray tube and the centre of rotation (isocenter) of CT scanners. Differences also exist in filtration of the X-ray beams, efficiency of detection systems, noise levels in data acquisition electronics and reconstruction algorithms [18]. Thus, radiation dose, obtained, at a given kVp and mAs on one scanner model may differ considerably from that obtained on another scanner model.

In a related paper, McKenney et. al. [26], in agreement with this work on variation in radiation dose levels of CT scanners when protocols are migrated from one CT scanner to the other, reported in their work that while some protocol parameters such as tube kilovolt, (kV), gantry rotation time, etc., can remain constant between scanners, the automatic exposure control parameter, responsible for the selection of the overall mA level during tube current modulation, is difficult to match between scanners, especially from different CT manufacturers. They went ahead to model methods to translate the scanning protocols between scanners.

Conclusions

CT radiation effective dose values from eight CT scanners were calculated by a CT dose calculator, CT-RADOSE, using the same CT scanning protocol. These values were compared, and considerable differences were established between them. The effect of this variation in effective doses is an increased risk of radiation exposure (stochastic and deterministic effects) for patients who undergo CT examinations in diagnostic centres where this practice of migration of technique factors between CT scanners is being practiced. Consequently, when scan protocols are prepared for a scanning session, it is important to be cautious about 'transfer' of parameters from one scanner model or manufacturer to another. Health personnel in diagnostic centers, especially in the developing countries, where the number of qualified diagnostic health workers is limited, should be made to undergo periodic training to upgrade their knowledge on current methods in the concept of CT, radiation dose and possible risks to protect patients from unnecessary radiation exposure that can put the patients in potential radiation risk.

Abbreviations

CT: Computed tomography; GE: General Electric; kV: kilovolt; ANOVA: Analysis of variance.

Author Contributions

The authors contributed equally to this study.

Competing Interests

The authors have declared that no competing interest exists.

References

[1] Dowsett, D., Kenny, P.A., & Johnson, R.E. (2006). *The Physics of Diagnostic Imaging (2nd ed)*. CRC Press.

[2] https://www.consumerreports.org/cro/magazine/2015/01/the-suprising-dangers-of-ctscans-and-x-rays. Accessed 25 March 2022.

[3] National Council on Radiation Protection and Measurements (2019) Medical radiation exposure of patients in the United States, NCRP report 184. National Council on Radiation Protection and Measurements, Bethesda.

[4] Surgeons (AAOS), American Academy of Orthopaedic; Physicians (ACEP); American College of Emergency; UMBC (2017). *Critical Care Transport*. Jones and Bartlett Learning, p. 389.

[5] Bin Saeedan, M., Aljohani, I. M., Khushaim, A. O., Bukhari, S. Q., & Elnaas, S. T. (2016). Thyroid computed tomography imaging: pictorial review of variable pathologies. *Insights into imaging*, *7*(4), 601-617.

[6] Nickoloff, E. L., & Alderson, P. O. (2001). Radiation exposures to patients from CT: reality, public perception, and policy. *American Journal of Roentgenology*, 177(2), 285-287.

[7] Smith-Bindman, R., Lipson, J., Marcus, R., Kim, K. P., Mahesh, M., Gould, R., De González, A. B. & Miglioretti, D. L. (2009). Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. *Archives of internal medicine*, *169*(22), 2078-2086.

[8] Alsafi, K. G. (2016). Radiation protection in X-ray computed tomography: literature review. *International Journal Radiology and Imaging Technology*, *2*(2), 1-5.

[9] Jeukens, C. R., Boere, H., Wagemans, B. A., Nelemans, P. J., Nijssen, E. C., Smith-Bindman, R., Wildberger, J. E. & Sailer, A. M. (2021). Probability of receiving a high cumulative radiation dose and primary clinical indication of CT examinations: a 5-year observational cohort study. *BMJ open*, *11*(1), e041883.

[10] Costello, J. E., Cecava, N. D., Tucker, J. E., & Bau, J. L. (2013). CT radiation dose: current controversies and dose reduction strategies. *AJR. American Journal of Roentgenology*, *201*(6), 1283-1290.

[11] Hong, J. Y., Han, K., Jung, J. H., & Kim, J. S. (2019). Association of exposure to diagnostic low-dose ionizing radiation with risk of cancer among youths in South Korea. *JAMA network open*, *2*(9), e1910584-e1910584.

[12] Brenner, D. J., Elliston, C. D., Hall, E. J., & Berdon, W. E. (2001). Estimated risks of radiation-induced fatal cancer from paediatric CT. *American journal of roentgenology*, 176(2), 289- 296.

[13] Thomas, K. E., Parnell-Parmley, J. E., Haidar, S., Moineddin, R., Charkot, E., BenDavid, G., & Krajewski, C. (2006). Assessment of radiation dose awareness among pediatricians. *Pediatric radiology*, *36*, 823-832.

[14] Donnelly, L. F., Emery, K. H., Brody, A. S., Laor, T., Gylys-Morin, V. M., Anton, C. G., Thomas, S. R. & Frush, D. P. (2001). Minimizing radiation dose for pediatric body applications of single-detector helical CT: strategies at a large children's hospital. *American Journal of Roentgenology*, *176*(2), 303-306.

[15] Lee, C. I., Haims, A. H., Monico, E. P., Brink, J. A., & Forman, H. P. (2004). Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. *Radiology*, *231*(2), 393-398.

[16] Leitz, W., Axelsson, B., & Szendrö, G. (1995). Computed tomography dose assessment-a practical approach. *Radiation Protection Dosimetry*, 57(1-4), 377-380.

[17] Rehani, M. M., & Berry, M. (2000). Radiation doses in computed tomography: the increasing doses of radiation need to be controlled. *BMJ: British Medical Journal*, 320(7235), 593.

[18] ICRP (2007). Managing Patients Dose in Multi Detector Computed Tomography (MDCT). *ICRP Publication 102*. Ann. ICRP 37(1), 1-79.

[19] Huda, W., Atherton, J. V., Ware, D.E., & Cumming, W. A. (1997). An approach for the estimation of effective radiation dose at CT in paediatric patients. *Radiology*, 203(2), 417-422.

[20] Theocharopoulos, N., Damilakis, J., Perisinakis, K., Tzedakis, A., Karantanas, A., & Gourtsoyiannis, N. (2006). Estimation of effective doses to adult and pediatric patients from multislice computed tomography: a method based on energy imparted. *Medical physics*, *33*(10), 3846-3856.

[21] Huda, W., Scalzetti, E. M., & Levin, G. (2000). Technique factors and image quality as functions of patient weight at abdominal CT. *Radiology*, *217*(2), 430-435.

[22] Ware, D. E., Huda, W., Mergo, P. J., & Litwiller, A. L. (1999). Radiation effective doses to patients undergoing abdominal CT examinations. *Radiology*, 210(3), 645-650.

[23] Huda, W., Scaletti, E. M., & Roskopf, M. (2000). Effective doses to patients undergoing thoracic computed tomography examinations. *Medical Physics*, 27(5), 838-844.

[24] Huda, W., Lieberman, K. A., Chang, J., & Roskopf, M. L. (2004). Patient size and x-ray technique factors in head computed tomography examinations. I. Radiation doses. *Medical Physics*,31(3),588-594.

[25] ImPACT Imaging Performance Assessments of CT. CT Patient Dosimetry Spreadsheet (v1.03,24/08/2010). http:/www.impactscan.org/download/ctdosimetrydownload.htm

[26] McKenney SE, Seibert JA, Lamba R, Boone JM. (2014). Methods for CT Automatic Exposure Control Protocol Translation between Scanner Platforms. *American College of Radiology*.,11(3), 285–291.