Derivation of Dose Conversion Factors by Measurement of Patients' Organ Size in Computed Tomography Machine

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ABSTRACT
Diagnostic radiology requires an advance form of dosimetry, for its reliable use during exposures in Computed Tomography. Samples of some patient exposure data on Abdominopelvic region of the body was collected from a hospital for use. The organ length or dimension for the Anterior Posterior (AP), Lateral (LAT), Patient Weight and Computed Tomography Dose Index volume (CTDIvol), makes up the data used. The product of the conversion factor f_{size}^{16} or f_{size}^{32} , based on the patient, and the CTDIvol, gives the Size Specific Dose Estimate (SSDE). The CTDIvol mean was 8.85mGy, range 4.02 mGy – 13.68 mGy. AP mean was 5.46 cm, range 1.86 cm – 15.4 cm. LAT mean was 10.46 cm, range 3.3 cm – 18.97 cm. f_{size}^{32}(AP) mean was 1.83, range 0.62 – 5.16. f_{size}^{32}(LAT) mean was 3.47, range 1.09 – 6.28. SSDE (AP) mean was 15.88 mGy, range 5.40 mGy – 50.80 mGy. SSDE (LAT) mean was 30.94 mGy, range 7.63 mGy – 64.03 mGy and Patient Weight mean was 80.6 kg, range 64 kg – 97 kg. The SSDEs (AP or LAT), was seen to vary with the lengths or dimensions of the patients. The amount of absorbed dose on exposure was more for greater lengths. Therefore, there is a need to estimate the dosage before exposure is done for a patient, to minimize any excess of usage of radiation, that can cause an unwanted side effect.

Keywords
Dosimetry, exposure, estimate, organ, dimension, absorbed dose, radiation.

1. INTRODUCTION
Computed Tomography (CT) scanners, has found its use to be on the increase, in present modern day diagnostic radiology [1 – 2]. One reason for this wide use is that they provide high quality image in 3D [3], with very fast acquisition time [4]. Images quality are characterized by high spatial resolution, low noise level, and high contrast to differentiate between different tissues [5].

Scans from CT has been considered a useful and powerful modality to medical practitioners, nevertheless, it has also been found to contribute to most of the medical dose exposures experienced by patients. It is reported that approximately 25% of all radiological examinations were CT scans, by the International Atomic Agency (IAEA) [1]. Therefore, it is important for CT users and custodians to be knowledgeable about CT radiation issues, and also the methods for estimating, controlling and reducing dose levels, while still been able to maintain image quality.

It is vital to have the knowledge, of the process to estimate or calculate the baseline dose levels for each organ of the body during a CT scan. This can then serve as a control mechanism, for the amount of CT radiation that is safe, to use for patients during examinations. The amount of dose that is delivered during CT scans is more than those from conventional radiography and fluoroscopy [6 – 7]. It is very important that all medical radiation exposures should be justified, as low as reasonably achievable (ALARA) and should not exceed the expected individual dose limits [8]. It should be noted that present day radiation dose can produce some negative side effects [9]. It is therefore reasonable to report patient dose from any form of radiological exposures and uses of ionizing radiation.

CT scans can be either done to the head or any part of the body, depending on the patients need to do an examination. The Computed Tomography Dose Index volume (CTDI vol16 or CTDI vol32) are provided on the scanner screen [10]. Present day CT scanners normally displays the Computed Tomography Dose Index (CTDIvol) and the dose length product (DLP) dose indices [11 – 16], both before and after the CT scan is performed. This has been expected of manufacturers since 2002 [17]. The purpose of developing CTDIvol is to provide a standardized method to compare radiation output levels between different CT scanners using a reference phantom. Note that the CTDIvol can be determined for either a 16 cm or 32 cm diameter polymethyl methacrylate (PMMA) cylindrical reference phantom, this is often called the "head" or "body" CTDIvol phantom, respectively [18].

Patient size and output radiation of scanner are both what determines the dose received from CT scan, by the patient. Only output from the scanner is what CTDI vol as an information. The patient size is not address, and so it does not estimate patient absorbed dose [19].

This research work seeks to develop and derive factors of conversion, which can be applied to what is the CTDIvol, the Volume Computed Tomography Dose Index (CTDIvol), which is a key metric in medical imaging, measured in milligray (mGy), that represents the average radiation dose delivered per CT scan slice, a dose index displayed and to also assist practitioners to be able to estimate or calculate dose of patient. This approach can be helpful in the effort to decrease the organ dose levels, and then also the image quality is maintained, without losses. It should be noted that CTDIvol can only give the scanner output. It does not take into account the size of the patient to which the dose was delivered, and so therefore it does not show the absorbed dose [20].

2. METHODOLOGY
2.1. Measurements of patients' body organ parts and CTDIvol
Patient exposure data of adult CT Abdominopelvic region of the body were collected from a hospital radiological section, for use. The sample data comprises of various organs of the body, organ length or dimension of the Anterior Posterior (AP)

and Lateral (LAT) part of the body, patient weight and the CTDIvol, as depicted in Table 1.

Table 1. Abdominopelvic Organs Measurements.

		Organs Length or Dimension (cm)			
S/N	Organs	AP	LAT	Patient Weight (kg)	CTDIvol (mGy)
1	LIVER	8.86	14.90	79	4.36
2	LEFT KIDNEY	5.42	11.53	82	6.57
3	RIGHT KIDNEY	3.94	10.40	86	7.24
4	STOMACH	6.37	13.14	90	11.4
5	LIVER	12.50	17.30	86.50	9.12
6	LEFT KIDNEY	4.50	10.37	68	5.63
7	SPLEEN	3.71	8.67	76	7.44
8	STOMACH	5.48	11.59	76	11.67
9	LEFT KIDNEY	3.76	9.37	74	11.40
10	SPLEEN	5.36	7.92	90	13.41
11	RIGHT KIDNEY	4.44	11.28	85	13.68
12	LIVER	14.88	18.97	82.50	10.19
13	LEFT KIDNEY	5.51	6.32	70	6.57
14	LEFT KIDNEY	4.41	6.20	65	6.30
15	LIVER	15.40	18.90	74	6.57
16	SPLEEN	3.98	7.19	82	9.79
17	STOMACH	7.44	15.63	80	9.26
18	LEFT KIDNEY	3.95	5.85	72	5.37
19	GALL BLADDER	3.34	7.05	64	8.32
20	GALL BLADDER	3.01	3.30	73	6.98
21	STOMACH	5.77	16.11	89	6.78
22	LEFT KIDNEY	4.01	5.99	76	4.02
23	GALL BLADDER	1.86	4.54	89	9.93
24	SPLEEN	4.95	10.55	97	8.59
25	GALL BLADDER	2.08	7.84	78	9.12
26	SPLEEN	4.50	11.42	88	13.55
27	GALL BLADDER	1.86	6.63	92	12.21
28	SPLEEN	4.96	12.19	78	12.07
29	STOMACH	2.20	12.28	91	8.99

2.2 Derivation of the conversion factors

However, the conversion factors of f_{size}^{32} was derived from Table 1B and Table 1C of Table 1(18). Equations (1) and (2) gives the derived formula for the conversion factors of AP and LAT, f_{size}^{32}, of each body CT scans, for the various organs, using the dimensions, as appropriate. An AP (Anteroposterior) body scan refers to an X-ray or CT imaging technique where the beam passes from the front (anterior) to the back (posterior) of the body. CT scanners are commonly used for rapid, detailed imaging of the abdomen, pelvis, or chest. It is primarily used to diagnose abdominal pain, injuries, or to visualize organs, bones, and blood vessels. LAT (Lateral) body scan, commonly a lateral X-ray or CT (neck, chest, or spine), images the body from the side, with the patient positioned sideways against the detector to evaluate spinal alignment, soft tissues, or specific injuries.

CT scans is good in alignments of body scans, soft tissues, or specific injuries. It is a standard diagnostic tool used to visualize structures in a sagittal plane, such as the thoracic spine or airway.

$$f_{size}^{32}\ (AP) = \frac{DIM\ (AP) \times 2.68}{8} \quad \text{.............................} \quad (1)$$

$$f_{size}^{32}\ (LAT) = \frac{DIM\ (LAT) \times 2.65}{8} \quad \text{........... ....} \quad (2)$$

Where DIM stands for dimensions of the AP and LAT of organs of the body scanned with the CT.

2.3 Determination of Size Specific Dose Estimate (SSDE)

The Size Specific Dose Estimate (SSDE), can be determined by the product of the CTDIvol and the conversion factors of f_{size}^{16} or f_{size}^{32} , as given by equation (3).

$$SSDE\ = CTDIvol\ \times\ f_{size}^{16}\ \text{or}\ f_{size}^{32} \quad \text{.......... ....} \quad (3)$$

Where the conversion factors, f_{size}^{16} is use for the head scan and f_{size}^{32} is use for the body scan. So therefore, for this work, we have used the f_{size}^{32} conversion factor, because the data were adult body CT scans.

Hence the SSDE can now be estimated as,

$$SSDE\ = CTDIvol\ \times\ f_{size}^{32} \quad \text{.................. ....} \quad (4)$$

2.4 MATLAB programming code for the calculations of the SSDEs

```
% SSDE Calculation Script for Body CT scans
clear; clc;
% Definitions of terms and parameters
% SSDE: Size Specific Dose Estimate:
% CTDIvol: Volume Computed Tomography Index
% f_size^16: Conversion factor use for the head scan (N/A: Not Applicable)
% f_size^32: Conversion factor use for the body scan
% AP: Anteroposterior
% LAT: Lateral
% DIM(AP) Dimension of the AP organ
% DIM(LAT): Dimension of the LAT organ
% 1. Input Parameters
ctdi_vol = input ('Enter the CTDIvol value (mGy): ');
dim_ap = input ('Enter the Anteroposterior Dimension (AP) in cm: ');
dim_lat = input ('Enter the Lateral Dimension (LAT) in cm: ');
% 2. Calculate Conversion Factors (f_size) based on Equations 1 and 2
% f_size^32 (AP) = (DIM(AP) * 2.68) / 8
f_size_ap = (dim_ap * 2.68) / 8;
% f_size^32 (LAT) = (DIM(LAT) * 2.65) / 8
f_size_lat = (dim_lat * 2.65) / 8;
% 3. Calculate SSDE for both AP and LAT as per Equation 3
% SSDE = CTDIvol * f_size^32
ssde_ap = ctdi_vol * f_size_ap;
```

```
ssde_lat = ctdi_vol * f_size_lat;
% 4. Display Results
fprintf ('\n--- Calculation Results ---\n');
fprintf ('Conversion Factor (AP): %.4f\n', f_size_ap);
fprintf ('Conversion Factor (LAT): %.4f\n', f_size_lat);
fprintf ('SSDE based on AP: %.4f mGy\n', ssde_ap);
fprintf ('SSDE based on LAT: %.4f mGy\n', ssde_lat);
% End of programming code using
% MATLAB
% N/A: Not Applicable
```

Table 2. Derived conversion factors of Organs AP and LAT dimensions of the body CT scan.

		Organs Length or Dimension (cm)			
S/N	Organs	AP	LAT	f^{s2} (AP)	f^{s2} (LAT)
1	LIVER	8.86	14.9	2.97	4.94
2	LEFT KIDNEY	5.42	11.53	1.82	3.82
3	RIGHT KIDNEY	3.94	10.40	1.32	3.45
4	STOMACH	6.37	13.14	2.13	4.35
5	LIVER	12.5	17.3	4.19	5.73
6	LEFT KIDNEY	4.50	10.37	1.51	3.44
7	SPLEEN	3.71	8.67	1.24	2.87
8	STOMACH	5.48	11.59	1.84	3.84
9	LEFT KIDNEY	3.76	9.37	1.26	3.10
10	SPLEEN	5.36	7.92	1.80	2.62
11	RIGHT KIDNEY	4.44	11.28	1.49	3.74
12	LIVER	14.88	18.97	4.98	6.28
13	LEFT KIDNEY	5.51	6.32	1.85	2.09
14	LEFT KIDNEY	4.41	6.20	1.48	2.05
15	LIVER	15.4	18.9	5.16	6.26
16	SPLEEN	3.98	7.19	1.33	2.38
17	STOMACH	7.44	15.63	2.49	5.18
18	LEFT KIDNEY	3.95	5.85	1.32	1.94
19	GALL BLADDER	3.34	7.05	1.12	2.34
20	GALL BLADDER	3.01	3.30	1.01	1.09
21	STOMACH	5.77	16.11	1.93	5.34
22	LEFT KIDNEY	4.01	5.99	1.34	1.98
23	GALL BLADDER	1.86	4.54	0.62	1.50
24	SPLEEN	4.95	10.55	1.66	3.49
25	GALL BLADDER	2.08	7.84	0.70	2.60
26	SPLEEN	4.50	11.42	1.51	3.78
27	GALL BLADDER	1.86	6.63	0.62	2.20
28	SPLEEN	4.96	12.19	1.66	4.04
29	STOMACH	2.20	12.28	91	8.99

By employing equation (4), the SSDE, can be calculated for each patient. Table 3 presents the values of the SSDE for the CT scans.

3. RESULTS AND DISCUSSION

The results of the SSDEs obtained for AP and LAT positions of the body CT examinations, as well as the organs lengths, are presented in Table 3.

Table 3. Size Specific Dose Estimate (SSDE) for each patient CT scan.

		Organs Length or Dimension (cm)			
Patient S/N	Organs	AP (cm)	LAT (cm)	SSDE (mGy) (AP)	SSDE (mGy) (LAT)
1	LIVER	8.86	14.90	12.94	21.52
2	LEFT KIDNEY	5.42	11.53	11.93	25.09
3	RIGHT KIDNEY	3.94	10.40	9.56	24.94
4	STOMACH	6.37	13.14	24.33	49.62
5	LIVER	12.50	17.30	38.19	52.26
6	LEFT KIDNEY	4.50	10.37	8.49	19.34
7	SPLEEN	3.71	8.67	9.25	21.37
8	STOMACH	5.48	11.59	21.42	44.8
9	LEFT KIDNEY	3.76	9.37	14.36	35.38
10	SPLEEN	5.36	7.92	24.08	35.18
11	RIGHT KIDNEY	4.44	11.28	20.35	51.12
12	LIVER	14.88	18.97	50.8	64.03
13	LEFT KIDNEY	5.51	6.32	12.13	13.75
14	LEFT KIDNEY	4.41	6.20	9.31	12.94
15	LIVER	15.40	18.90	33.89	41.13
16	SPLEEN	3.98	7.19	13.05	23.32
17	STOMACH	7.44	15.63	23.08	47.94
18	LEFT KIDNEY	3.95	5.85	7.11	10.41
19	GALL BLADDER	3.34	7.05	9.31	19.43
20	GALL BLADDER	3.01	3.30	7.04	7.63
21	STOMACH	5.77	16.11	13.11	36.18
22	LEFT KIDNEY	4.01	5.99	5.40	7.98
23	GALL BLADDER	1.86	4.54	6.19	14.93
24	SPLEEN	4.95	10.55	14.24	30.02
25	GALL BLADDER	2.08	7.84	6.35	23.68

26	SPLEEN	4.50	11.42	20.43	51.26
27	GALL BLADDER	1.86	6.63	7.61	26.82
28	SPLEEN	4.96	12.19	20.06	48.74
29	STOMACH	6.63	36.57	2.20	12.28

The estimated SSDE for each patient scans are presented, with the corresponding organ length or

dimension. The CT machine generated CTDIvol, are shown on the Table 1. Each conversion factors for AP and LAT, can also be seen across the various organ types, with the patient arranged in serial number (S/N) in Table 2.

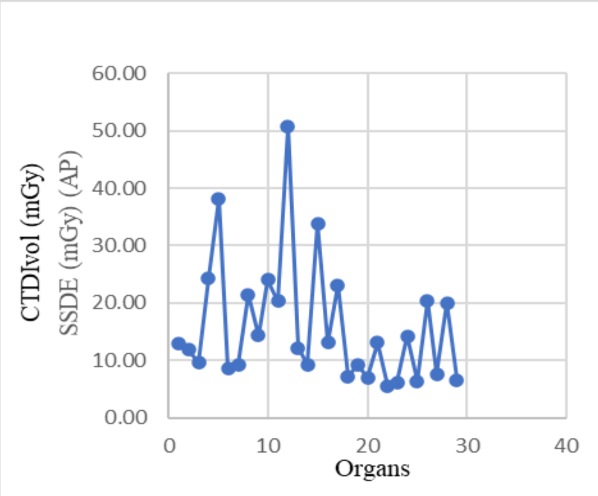

Fig. 1. Variation of SSDE (AP) (mGy) and CTDIvol (mGy) for each organ of the body.

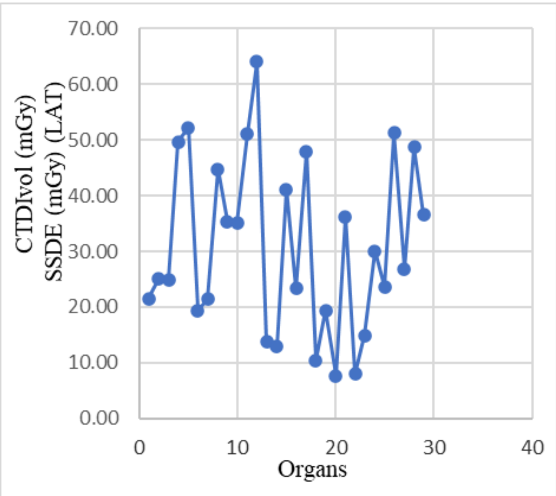

Fig. 2. Variation of SSDE (LAT) (mGy) and CTDIvol (mGy).

In Fig., 1 and Fig. 2., the SSDEs varies in proportion to the CTDIvol for each organ. As the length or dimension of the organ increases, so the value of the SSDE. Greater length or dimension, means a high SSDE. The highest SSDE in Fig. 1., was found to be Liver at 50.80 mGy (AP), and lowest was Stomach at 6.63 mGy (AP). The highest SSDE in Fig. 2., was found to be Liver at 64.03 mGy (LAT), and lowest was Gall Bladder at 7.63 mGy (LAT).

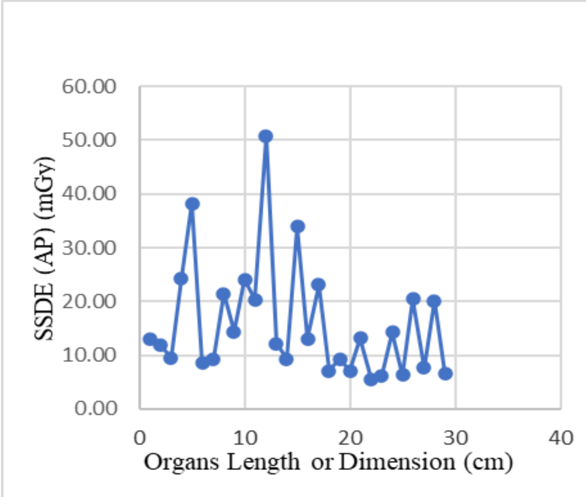

Fig. 3. Variation of SSDE (AP) (mGy) and Organ length or dimension (cm).

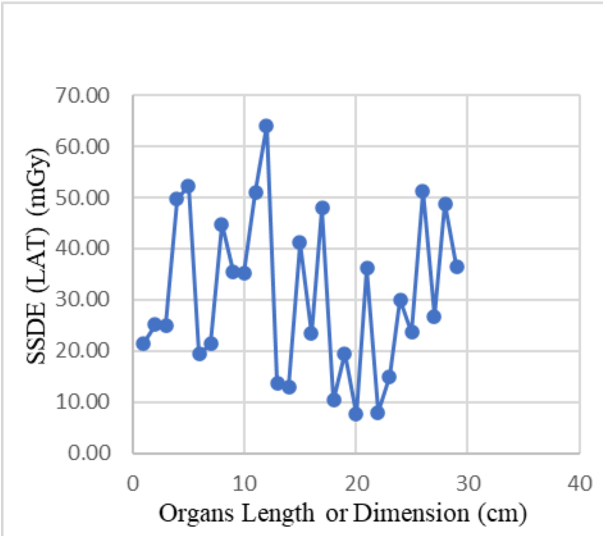

Fig. 4. Variation of SSDE (LAT) (mGy) and Organ length or dimension (cm).

From Fig. 3. and Fig. 4., the SSDE shows variation with the organ's length or dimension. The greater the length or dimension the higher the SSDE. In Fig. 3., highest SSDE (AP) was found to be Liver at 50.80 mGy with length or dimension 14.88 cm. Lowest SSDE (AP) was Left Kidney at 5.40 mGy with length or dimension 4.01 cm. Also, in Fig. 4., highest SSDE (LAT) was found to be Liver at 64.03 mGy with length or dimension 18.97 cm, lowest SSDE (LAT) was Gall Bladder at 7.63 mGy of length or dimension of 3.30 cm.

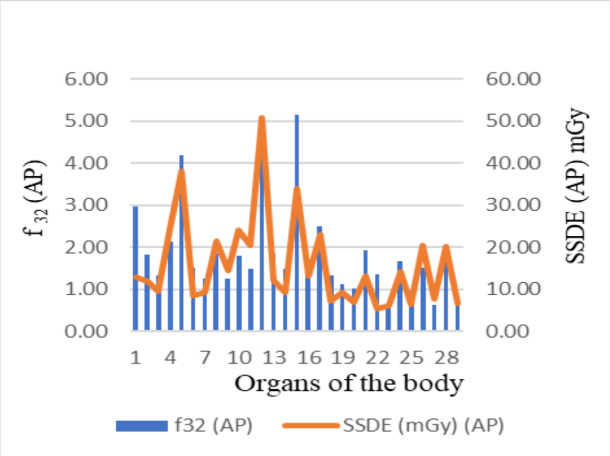

Fig. 5. Variation of f32 (AP) and SSDE (AP) mGy.

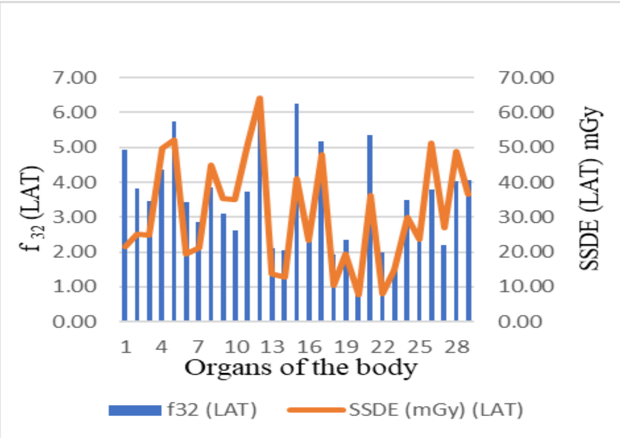

Fig. 6. Variation of f32 (LAT) and SSDE (LAT) mGy.

In Fig. 5. and Fig.6., the derived f_{32} (AP or LAT) contributes to the final output of the radiation dose SSDE (AP or LAT) mGy, of each patients' body, at the CT examination. This contribution also varies from one patient to the other.

The specifications in Engineering terms for the CT machine used for the examinations, of the patients was set at the optimum values, as depicted in Table 4, together with the model type.

Table 4. Engineering specifications of the CT machine.

Model: Siemens 64 Slices
Slice Count
Gantry Aperture
Heat Storage (MHU)
Tube Cooling
kW Output
mA Range
Max Load Capacity
Reconstruction Matrices
Suggested Room Size (m^2)

4. CONCLUSION

Given that the CTDIvol is not the exact dose to a patient, undergoing a CT examination, the actual dose can thus be derived and determined by the Size Specific Dose Estimate (SSDE), as it has been done by this research work.

The effectiveness of CT machines in clinical use, cannot be overemphasized. But however, there is a need to carefully monitor, measure and control its output, in order to deliver the amount of dose at the output for safety and reliability.

For this research work, the highest dose was found in Livers at SSDE (LAT) of 64.03 mGy, having length or dimension of 18.97cm, with lowest dose found in Left Kidney at SSDE (AP) of 5.40 mGy, having a length or dimension of 4.01cm.

It should also be noted that the SSDE, can be estimated for any organ parts of the body like, head and neck, chest (thorax), abdomen and pelvis, vascular system (CT Angiography – CTA), musculoskeletal system (extremities and spine), and many more.

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Conflicts of Interest: The authors declare no conflicts of interest.

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