# A RETROSPECTIVE CROSS-SECTIONAL STUDY TO ESTIMATE THE DOSE LENGTH PRODUCT (DLP) USING MULTI-SLICE COMPUTED TOMOGRAPHY OF CT HEAD BASED ON SEX AND BODY WEIGHT IN NORTH INDIA

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## Abstract

**Background:** DLP is frequently employed in computed tomography as a radiation dosage indication. This study examined the importance of body weight and sex in DLP-based radiation dose monitoring. Ten different scanners that produced 300 computed tomography scans of the head were examined. The DLP and body weight were evaluated individually for men and women using linear regression. The DLP and body weight had a favourable relationship, and each scanner had a unique dependence on sex and weight. The radiation dose and its influence on sex and weight were more easily compared between scanners using traditional DLP values that had been weight and sex corrected. It was possible to detect examinations with potentially high dosages without considering importance by adjusting the DLP for sex and weight. Tracking the DLP concerning sex, body mass, and daily observations will make it easier to compare the radiation exposure across imaging methods, scanners, and unexpected variance.

**Purpose:** To investigate the significance of sex and body weight (BW) in dose length products (DLP) based on radiation dose monitoring. To estimate patient doses in the head examination using computed tomography and calculate organ dose.

**Methodology**

Three hundred (300) single-phase (plain or unenhanced) computed tomography examinations of the head, performed from March 15 2022 to September 30 2022, on 10 different scanners, were analysed.

**Result:** Variations exist in DLPs between the different scanners due to protocol variations with different types of CT scanners. The DLPs values for 10 other scanners were as follows: 773.66 ± 365.60 and 1.62 ± 0.77, 1058.30 ± 225.34 and 2.22 ± 0.47, 951.10 ± 130.91 and 2.00 ± 0.28, 641.76±317.20 and 1.32 ± 0.70, 976.23±154.61 and 2.05 ± 0.32, 943.26±140.23 and 1.98 ± 0.29, 540.00±128.68 and 1.13 ± 0.27, 555.63±120.24 and 1.13 ± 0.31, 458.10±73.57 and 0.96 ± 0.15.

**Conclusion**: The current study found that body weight and gender are essential in DLP-based head CT radiation monitoring. DLP varies with gender and body weight. DLP's link to sex and weight reflects imaging radiation dosage. Adjusting the DLP for sex and weight reduces population-based bias, making comparing imaging processes and scanners easier. The modification helps detect unanticipated radiation exposure discrepancies.

DLP and ED for standard head protocol were lower than EU recommendations (EC). Even though DLP and effective Dose were more melancholy than EC, diagnostic image quality was unaltered.

**Keywords: DLP, DRL, CT Head, Body weight, Sex, Radiation Dose**

## Introduction

The introduction of medical imaging started with the discovery of Rontgen rays called X-rays. Mechanical engineer and physicist Wilhelm Conrad Rontgen of Germany discovered x-rays on November 8, 1895. Roentgen took the first x-ray of a human being, which was his wife's hand. That iconic photo marked the first application of radiography as a diagnostic tool. The use of x-rays for imaging human anatomy has progressed steadily ever since the discovery of the technology. Different types of imaging (radiography, fluoroscopy, computed tomography) require different detectors to pick up x-rays with varying intensities after interacting with the patient's anatomy1,2. The patient is positioned so that the x-ray source is on one side of them, and the detector is on the other, to image them using x-rays.

It is believed that increasing radiation exposure through computed tomography (CT) will increase the risk of developing cancer, and this issue is well-acknowledged in modern medicine [3,4,5]. In a personal examination, reducing radiation increases image noise, degrading image quality. AEC and iterative (IR) image reconstruction are two examples of the ongoing research and development of dose reduction methods that aim to lower radiation dose without sacrificing image quality[6,7]. The radiation dose for the relevant protocol must be evaluated to optimise the data collection and reconstruction approaches. For dosage reduction, thorough dose tracking is crucial, and different solutions are available [8,9]. Daily radiation dose monitoring is also desired to identify and steer clear of unforeseen, excessive radiation exposure.

Both the $CTDI_{VOL}$ and the DLP, which are automatically provided by a CT scanner, are frequently employed as markers of the radiation dosage in CT[10]. CTDIVOL represents the average radiation dosage along the z-axis, and the overall Dose delivered across the whole scan range is represented by the DLP, which is calculated as the sum of $CTDI_{VOL}$ and scan length. These parameters[11,12,13,14,15] have been used to provide diagnostic reference levels for CT. The product of DLP and a conversion factor selected by imaging region and age[16,17] is widely used to estimate the effective Dose (ED), a measure of radiation exposure reflecting the stochastic effect of ionising radiation, including cancer induction and heritable consequences. The DLP seems to be a valuable and helpful marker for keeping track of CT radiation dose. The DLP is recorded and analysed by dose-tracking systems.

Increasing size causes the tissues to attenuate more X-ray photons, reducing the number of photons detected. The tube current for X-ray emission is often modulated using AEC [18, 19] to obtain CT images of consistent quality. In a large patient, CTDIvol rises due to higher tube current, and a considerable body height may also lengthen the scan. Consequently, a large patient's DLP value may be unavoidably high [20]. Identifying improper, excessive radiation exposure in individual exams is hampered by such a difference in the DLP according to body size. Additionally, different regions of the world have varying standards for body size, which could skew global radiation dose comparisons.

This study examined the importance of body weight and sex in DLP-based radiation dose monitoring. The ongoing research compared body weight and DLP values for head CT scans done on ten different CT scanners. Men and women underwent the analysis independently.

**Purpose**

- To investigate the significance of sex and body weight (BW) in dose length products (DLP) based on radiation dose monitoring.
- To estimate patient doses in the head examination using computed tomography and calculate organ dose.

**Methodology**

**Subjects**

From March 15 2022, to September 30 2022, 300 single-phase (plain or unenhanced) head CT scans were done on 10 different scanners and analysed. The following inclusion criteria were applied:

**Study population**

- All records with requests for a head scan. The data has been collected from DICOM.

**The inclusion criteria were:**

- Adults aged 18-90 years
- Weight between 45-90 kg.
- Both genders.

Sample Adult DLP Data Collection at Different Centers

Age Group 18-80 Years

| Sr. No | Head (DLP in mSv) |
|---|---|
| DLP | 30 Cases |

**EXCLUSION CRITERIA**

**The Exclusion Criteria were:**

- Weight between > 90 kg
- Adults aged < 18 years

**Instrument of data collection**

Ten (10) CT scanners are used, and 30 examinations meeting the inclusion criteria will be selected consecutively for each sex and body weight for each of the ten scanners.

**Statistical analysis**

Range, mean, standard deviation (SD), median, frequencies (number of cases), and relative frequencies (percentages), where applicable, was used to characterise the data. The statistical tool SPSS 21version for Microsoft Windows and XLSTAT was used for all statistical calculations.

**Results**

The research was conducted in North India, including 10 (ten) CT scanners. The data was collected from DICOM and analysed. This research included three hundred (n=300) patients aged 18-90 referred for a head CT scan. One hundred twenty-three (123) patients were females, while one seventy-seven (177) were males.

The Dose length product provided by the scanners was higher in men than in women, irrespective of scanner table 7.

The DLP values were in the 116-1206 mGy.cm, and ED (effective Dose) were in the 0.176-2.526 mGy.

**Table 1: Summary statistics in all Scanners for head examination**

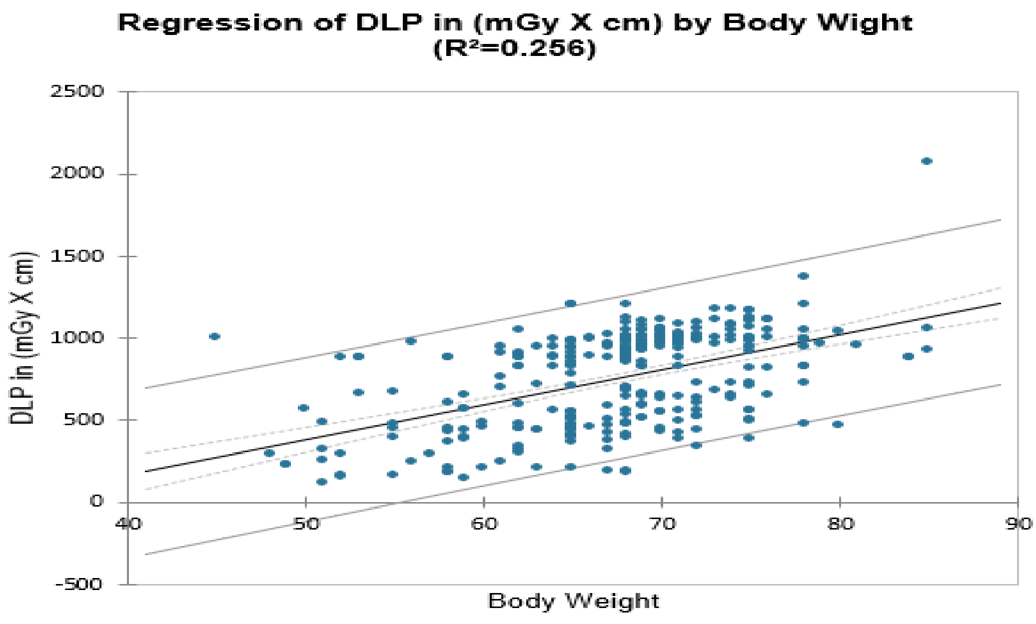
| Variable | Observations | Obs. with missing data | | | Obs. without missing data | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|---|---|---|---|
| DLP in (mGy X cm) | 300 | 0 | | | 300 | 116.000 | 2066.000 | 758.39 | 291.76 |
| Body Wight | 300 | 0 | | | 300 | 45.000 | 85.000 | 67.600 | 6.900 |

**Table 2: Regression of variable DLP in (mGy X cm) (n=300) in all Scanners for head examination**

| | |
|---|---|
| Male | 177 |
| Female | 123 |

| | |
|---|---|
| Observations | 300 |
| Sum of weights | 300 |
| DF | 298 |
| $R^2$ | 0.256 |
| $Q^2$ | 0.243 |

**Graph 1: Showing DLP & Body weight distribution in all Scanners for head examination**




Data collected from 10 scanners showing the age and body weight of males and females with mean & SD separately are shown in table 6.

**Table 3: Data collected from 10 scanners showing the age of males and females** with **mean & SD in all Scanners for head examination**

| S.no | Scanner | Age | | Mean ± SD | |
|---|---|---|---|---|---|
| | | Male | Female | Male | Female |
| 1 | 16 Slice GE Revolution | 17 | 13 | 39.00±19.23 | 40.15±21.71 |
| 2 | 16 Slice Siemens Emotion | 21 | 9 | 49.71±18.47 | 42.22±13.78 |
| 3 | 16 Slice Philips Brilliance | 20 | 10 | 43.75±16.00 | 58.80±22.39 |

| | | | | | |
|---|---|---|---|---|---|
| 4 | 32 Slice Siemens Scope | 17 | 13 | 35.47±15.41 | 56.38±15.54 |
| 5 | 08 Slice GE Revolution ACTs | 15 | 15 | 37.80±18.31 | 45.0±18.14 |
| 6 | 08 Slice Siemens Emotion | 16 | 14 | 53.94±19.07 | 51.71±17.73 |
| 7 | 64 Slice Siemens Somatom | 19 | 11 | 40.16±16.83 | 5.55±18.74 |
| 8 | 128 Slice Philips Ingenuity | 18 | 12 | 48.56±16.37 | 40.75±10.02 |
| 9 | 64 Slice Toshiba Aquilion | 16 | 14 | 38.78±12.89 | 46.86±13.24 |
| 10 | 64 Slice GE VCT | 18 | 12 | 45.50±20.11 | 47.17±19.99 |

The data taken from different scanners shows variation when compared to each other. A positive correlation was found between DLP results and body weight across all scanners and both sexes, as shown in Table 4. This research also shows that sex and body weight significantly affect radiation doses, as shown in Table 5. The Dose length product provided by the scanners was higher in men than in women irrespective of the scanner table 9. The study suggests that men receive more radiation doses than women on CT head examinations.

Data collected from ten different scanners were compared with each other, which shows patients who undergo an examination on Philips Brilliance 16 slice receives the highest dose length product (DPL) while those patients who undergo an examination under GE VCT 64 slice receives lowest dose length product (DPL) as shown in table 4.

**Table 4: Showing combined DLP received by patients on different scanners during CT head examination.**

| S.no | Scanner | DLP | | P-Value |
|---|---|---|---|---|
| | | Mean | SD | |
| 1 | 16 Slice GE Revolution | 685.86 | 273.27 | |
| 2 | 16 Slice Siemens Emotion | 773.66 | 365.60 | |

| | | | | |
|---|---|---|---|---|
| 3 | 16 Slice Philips Brilliance | 1058.30 | 225.34 | <0.001 |
| 4 | 32 Slice Siemens Scope | 951.10 | 130.91 | |
| 5 | 08 Slice GE Revolution ACTs | 641.76 | 317.20 | |
| 6 | 08 Slice Siemens Emotion | 976.23 | 154.61 | |
| 7 | 64 Slice Siemens Somatom | 943.26 | 140.23 | |
| 8 | 128 Slice Philips Ingenuity | 540.00 | 128.68 | |
| 9 | 64 Slice Toshiba Aquilion | 555.63 | 120.24 | |
| 10 | 64 Slice GE VCT | 458.10 | 73.57 | |

Our study also suggests that generally, men receive the highest dose length product (DPL) than females despite of given weight. DLP had a more considerable unadjusted variance among heavier subjects, suggesting that the highest risk of overdosing occurred in that population.

**DISCUSSION**

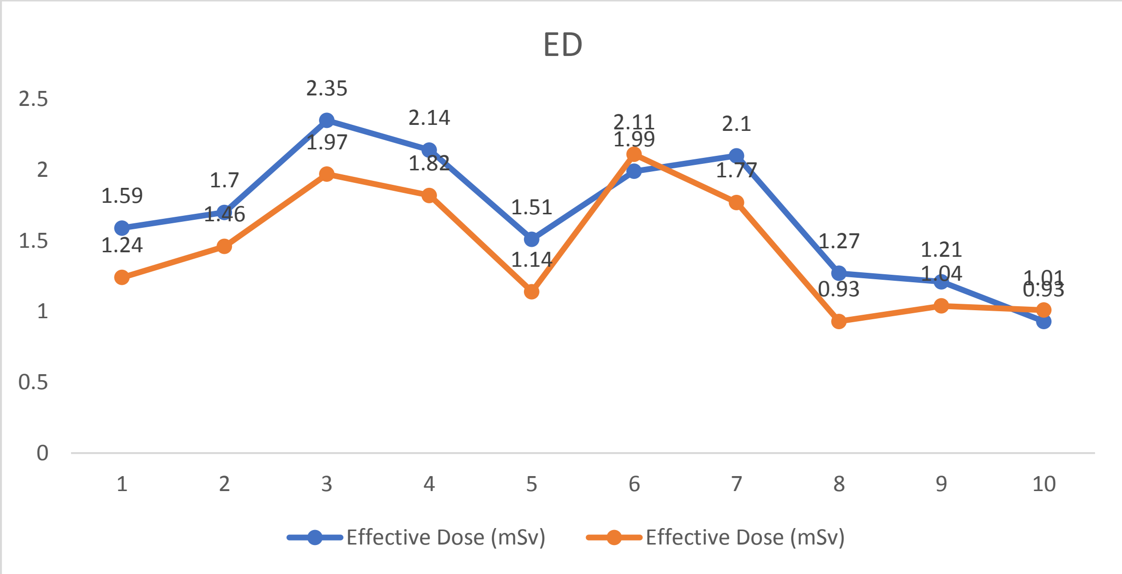
Plots showing how DLP and body weight are related. The DLP is typically used to calculate overall radiation exposure for a particular CT scan. Ten scanners were utilised in the current study to investigate the role of gender and body weight in DLP-based radiation dose monitoring. Image quality was not compared between scanners, and imaging settings for each scanner were selected empirically. When using different imaging procedures and scanners, the dependence on sex, weight, and DLP levels varied. It should be emphasised that the produced DLP values rely on the parameters and do not represent how well the scanner performed.

Three hundred patients underwent CT scans of head examination different 10 MSCT scanners, each MSCT Scanner examination consisting of 30 patients. The patients included were selected to correspond to the typical patient (weight 45-90 kg). The DLP and effective dose were calculated in the patient. For head protocol, the mean DLP after a scan and ED were 685.86 ± 273.27 mGy-cm and 1.44 ± 0.57 mSv for 16 Slice GE Revolution, 773.66 ± 365.60 mGy-cm and 1.62 ± 0.77 mSv for 16 Slice Siemens Emotion, 1058.30 ± 225.34 mGy-cm and 2.22 ± 0.47 mSv for 16 Slice Philips Brilliance, 951.10 ± 130.91 mGy-cm and 2.00 ± 0.28 mSv for 32 Slice Siemens Scope, 641.76±317.20 mGy-cm and 1.32 ± 0.70 for 08 mSv Slice GE Revolution ACTs, 976.23 ± 154.61 mGy-cm and 2.05 ± 0.32 mSv for 08 Slice

Siemens Emotion, 943.26 ± 140.23 mGy-cm and 1.98 ± 0.29 mSv for 64 Slice Siemens Somatom, 540.00 ± 128.68 mGy-cm and 1.13 ± 0.27 mSv for 128 Slice Philips Ingenuity, 555.63 ± 120.24 mGy-cm and 1.13 ± 0.31 mSv for 64 Slice Toshiba Aquilion, 458.10 ± 73.57 mGy-cm and 0.96 ± 0.15 mSv for 64 Slice GE VCT as shown in Table 5.

When considering the 64-slice GE VCT, the rise in DLP as a function of body mass was reasonably slight, as was mentioned before [21]. The AEC approach in this scanner has a predetermined maximum strength of size-dependent tube current modulation and quality reference mAs that reflect the tube current-time product in patients of standard size. Men saw a less weight-dependent rise in DLP on the 64 Slice GE VCT scanner than women. Table 5 demonstrates that men had higher DLPs than women when using the scanner. The higher DLP in men can be attributed, at least in part, to their greater body mass. This sex disparity in the DLP was found even when the 64-slice Toshiba Aquilion was compared at the same weight.

In this study, dose-length products were converted into effective doses to see the total amount of radiation received by an individual during a CT head examination. While comparing all ten CT scanners with each other, we found that in 16 Slice GE, revelation males received a mean dose of 1.59 (SD: 0.50) and females 1.24 (SD: 0.62), which is lesser than that of males, the same type of findings have been seen in 8 scanners out of 10 scanners. Only two scanners, 64 Slice GE VCT & 08 Slice Siemens Emotion, show that female patients received a higher patient dose than males in this study, as shown in Table 5.




**Graph 2: Showing mean effective doses received by male and female patients during CT head examination from each scanner**.

**Table 5: Showing mean effective doses received by male and female patients during CT head examination from each scanner.**

| S.no | Scanner | Effective Dose (mSv) | | | | ED (mSv) |
|---|---|---|---|---|---|---|
| | | Male | | Female | | All |
| | | Mean | SD | Mean | SD | Mean ± SD |
| 1 | 16 Slice GE Revolution | 1.59 | 0.50 | 1.24 | 0.62 | 1.44 ± 0.57 |
| 2 | 16 Slice Siemens Emotion | 1.70 | 0.74 | 1.46 | 0.84 | 1.62 ± 0.77 |
| 3 | 16 Slice Philips Brilliance | 2.35 | 0.54 | 1.97 | 0.11 | 2.22 ± 0.47 |
| 4 | 32 Slice Siemens Scope | 2.14 | 0.23 | 1.82 | 0.25 | 2.00 ± 0.28 |
| 5 | 08 Slice GE Revolution ACTs | 1.51 | 0.68 | 1.14 | 0.69 | 1.32 ± 0.70 |

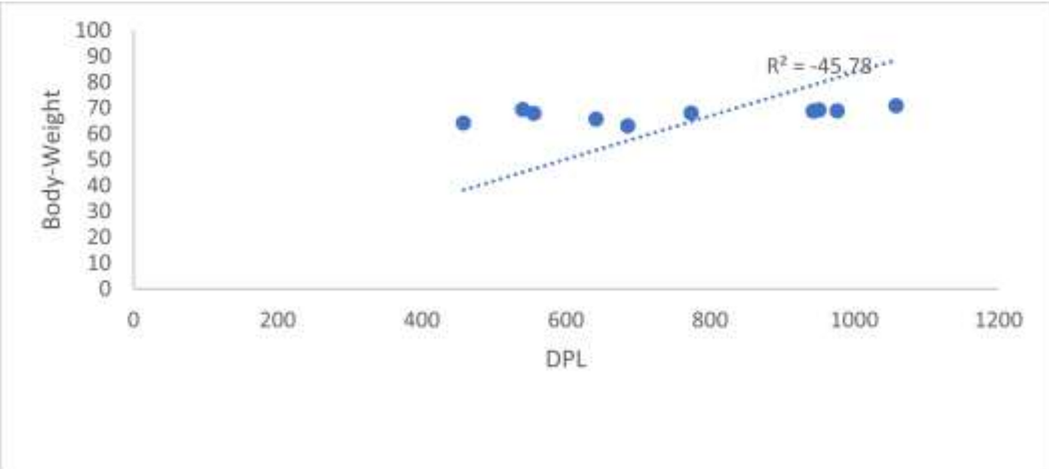
| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 08 Slice Siemens Emotion | 1.99 | 0.43 | 2.11 | 0.11 | 2.05 ± 0.32 |
| 7 | 64 Slice Siemens Somatom | 2.10 | 0.23 | 1.77 | 0.28 | 1.98 ± 0.29 |
| 8 | 128 Slice Philips Ingenuity | 1.27 | 0.23 | 0.93 | 0.20 | 1.13 ± 0.27 |
| 9 | 64 Slice Toshiba Aquilion | 1.21 | 0.26 | 1.04 | 0.35 | 1.13 ± 0.31 |
| 10 | 64 Slice GE VCT | 0.93 | 0.13 | 1.01 | 0.17 | 0.96 ± 0.15 |

During this study, the weight of all patients was recorded separately for each scanner for both gender patients, as shown in Table 6. In this study, the Body weight was compared with DLP for CT head examinations in all 10 scanners, as shown in Graph 1.

**Table 6: Showing mean body weight of male and female patients involved in this study from each scanner.**

| **S.no** | **Scanner** | **Body Weight (kg)** | | | |
|---|---|---|---|---|---|
| | | **Male** | | **Female** | |
| | | Mean | SD | Mean | SD |
| 1 | 16 Slice GE Revolution | 66.24 | 10.71 | 59.00 | 6.93 |
| 2 | 16 Slice Siemens Emotion | 68.90 | 9.32 | 66.00 | 8.26 |
| 3 | 16 Slice Philips Brilliance | 72.35 | 5.10 | 67.90 | 3.90 |
| 4 | 32 Slice Siemens Scope | 70.65 | 3.62 | 67.31 | 4.70 |
| 5 | 08 Slice GE Revolution ACTs | 69.27 | 9.22 | 61.93 | 6.70 |
| 6 | 08 Slice Siemens Emotion | 68.38 | 3.14 | 69.50 | 2.07 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | 64 Slice Siemens Somatom | 68.32 | 4.35 | 69.36 | 2.62 |
| 8 | 128 Slice Philips Ingenuity | 70.89 | 3.58 | 67.25 | 3.39 |
| 9 | 64 Slice Toshiba Aquilion | 69.13 | 4.32 | 66.57 | 6.73 |
| 10 | 64 Slice GE VCT | 64.83 | 8.91 | 63.33 | 7.03 |




**Graph 3: Comparing Body weight with DLP for CT head in all 10 scanners**

**Table 7: t-Test: Two-Sample Assuming Unequal Variances in all Scanners for head examination**

| | *DLP* | *Body-Weight* |
|---|---|---|
| Mean | 758.39 | 67.599 |
| Variance | 45198.95102 | 6.155832222 |
| Observations | 10 | 10 |
| Hypothesised Mean Difference | 0 | |
| df | 9 | |
| t Stat | 10.27431604 | |
| P(T<=t) one-tail | 1.42764E-06 | |
| t Critical one-tail | 1.833112933 | |
| P(T<=t) two-tail | 2.85527E-06 | |
| t Critical two-tail | 2.262157163 | |

**Table 8: t-Test: Two-Sample Assuming Equal Variances in all Scanners for head examination**

| | *DPL* | *Body-weight* |
|---|---|---|
| Mean | 758.39 | 67.599 |
| Variance | 45198.95102 | 6.155832222 |
| Observations | 10 | 10 |
| Pooled Variance | 22602.55343 | |
| Hypothesised Mean Difference | 0 | |
| df | 18 | |
| t Stat | 10.27431604 | |
| P(T<=t) one-tail | 2.93969E-09 | |
| t Critical one-tail | 1.734063607 | |
| P(T<=t) two-tail | 5.87937E-09 | |
| t Critical two-tail | 2.10092204 | |

Daily monitoring of individual examination DLP readings may aid in detecting and avoiding unexpected, excessive radiation exposures; nevertheless, the DLP is not intended to predict the risk of cancer induction in specific individuals. Significant body weight was associated with potentially high dosages in the current investigation, which was based on uncorrected DLP, but it did not seem to signal hazardous events. Size-dependent fluctuations in the DLP were minimised by adjusting for sex and weight, and it appears that this method may effectively identify real outliers.

DLP-based monitoring of the radiation dosage in head CT is important for patients of both sexes, as this study shows. Radiation dosage parameters of the imaging protocol are displayed by analysis of the DLP's association with body mass index and sex. It was discovered that the DLP varied between sexes and increased with weight gain. The DLP can be more comparable among imaging procedures and scanners if adjusted for sex and weight, removing bias caused by patient population variances. The modification also helps in the detection of unforeseen variations in radiation dose.

**Table 9: Showing DLP received by male and female patients during CT head examination.**

| **Scanner** | **DPL (mGy x cm)** | | |
|---|---|---|---|
| | **Male** | **Female** | **All** |

| | Mean | SD | Mean | SD | |
|---|---|---|---|---|---|
| 16 Slice GE Revolution | 759 | 237.34 | 589.69 | 296.11 | 685.86±273.27 |
| 16 Slice Siemens Emotion | 807.14 | 354.63 | 695.56 | 400.41 | 773.66±365.60 |
| 16 Slice Philips Brilliance | 1116.70 | 255.62 | 941.50 | 54.18 | 1058.30±225.34 |
| 32 Slice Siemens Scope | 1014.59 | 102.92 | 868.08 | 118.80 | 951.10±130.91 |
| 08 Slice GE Revolution ACTs | 771.40 | 273.62 | 512.13 | 312.32 | 641.76±317.20 |
| 08 Slice Siemens Emotion | 949.69 | 205.72 | 1006.57 | 51.34 | 976.23±154.61 |
| 64 Slice Siemens Somatom | 1000.26 | 110.88 | 844.82 | 134.38 | 943.26±140.23 |
| 128 Slice Philips Ingenuity | 603.61 | 107.98 | 444.58 | 95.28 | 540.00±128.68 |
| 64 Slice Toshiba Aquilion | 575.94 | 122.86 | 532.43 | 117.25 | 555.63±120.24 |
| 64 Slice GE VCT | 442.22 | 60.07 | 481.92 | 87.54 | 458.10±73.57 |

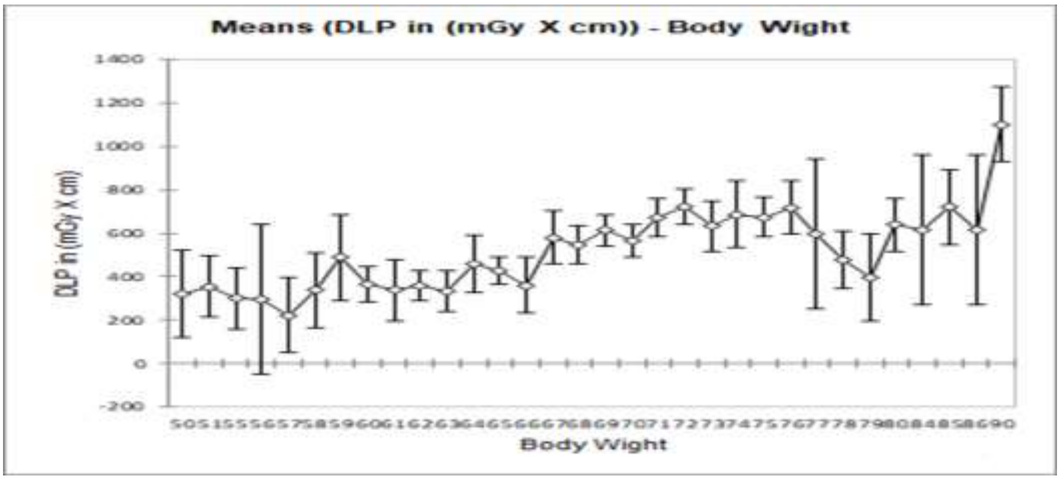
Linear regression is simple and only takes a minimal number of data points; it was utilised in the current investigation to weigh the DLP. For most assessments, patients self-reported their body weight, which may have reduced accuracy. Equations that are not linear might offer better adjustment.

Radiation exposures from 160 CT scans were studied by Elameen et al. in 2010 across three hospitals in Sudan[22]. Mean DLP values for adult patients ranged from 272-460 mGy-cm (head), 195-995 mGy-cm (chest), and 270-459 mGy-cm (body) based on a CT survey (abdomen). Each examination's effective dosage was calculated using CT dose indices, exposure-related data, and CTDI to influence dose conversion factors. Both the CT air kerma index and the dose length product fell below the criterion for acceptable radiation exposure established at the international level. Mean effective doses were 0.82 mSv for the brain, 3.7 mSv for the chest, and 5.4 mSv for the belly. Compared to other countries, Sudan had a lower effective dose per examination. Differences were found in CTDI, DLP, and ED.

CTDI (air) was studied by Abdullah et al., 2009, in 426 adults and 26 paediatrics CT scans performed in Malaysian hospitals. It gave the third-quartile practical dose values for all of the CT exams gathered, which can be used to set the dosage reference level for CT exams in Malaysia23. Studies conducted for European guidelines, the United Kingdom, and Taiwan all found the same range of effective doses for routine head, chest, and pelvic examinations. Compared to European guidelines and Taiwan studies, the effective Dose for the regular abdominal check was still within the range, although it was 55.1% greater than the result from the UK trial. CTDI and DLP were more excellent in this study than in the UK for all body locations scanned.

Oberg et al., 2007 determined the effective Dose and applied it to the medical field. Their goal was to determine the effective Dose (ED)[24]. In this study, these data promise to offer exposure doses to routine head, chest, and abdomen CT exams, which may then be used for standard protocol.

The optimal dosage was calculated and used in medicine by Oberg et al., 2007. Their objective was to estimate the ED[24]. These statistics promise exposure doses for the routine head, chest, and abdomen CT tests, which might be included in standard




**Graph 4: Showing Means (DLP in (mGy X cm)) - Body Wight in all Scanners for head examination**

practice.

The $CTDI_{VOL}$, DLP, and effective dosage for the routine head, cervical spine, abdominal, and chest inspections were determined by Mastora et al. (2009) and compared to the EC[25]. Researchers found the results were higher for head and chest checks but lower for the abdomen. A CT study found that adult patients' average DLP for the chest, cervical spine, and abdomen was 2.47, 7.53/9.87, 6.20, and 9.49/15.22 mSv, respectively25.

Doses given to patients getting CT scans have been the subject of multiple investigations. Research on the implementation of European Commission reference dose limits in Crete was provided by Tsapaki et al.[26]. To aid in the establishment of diagnostic reference levels in CT; studies were conducted and published by Papadimitriou et al.[27] and Hatziioannou et al.[28], respectively, who surveyed 14 CT scanners in Greece and 32 scanners in Italy. Moreover, there were also extensive polls in the UK, Taiwan, Iran, Italy, and Tanzania. Various countries' CTDI, DLP, and practical dose measurements are compared in Table 10.

**Table 10: Comparison of CTDI, DLP, and ED of CT head in different countries**

| | **TUTH** | **Taiwan**[29] | **Italy**[30] | **Wales**[31] | **Poland**[26] | **Tanzania**[32] | **Ireland**[33] | **Berlin**[34] | **UK**[26] |
|---|---|---|---|---|---|---|---|---|---|
| CTDI (mGy) | | | | | | | | | |
| Head | - | 55 | 59.6 | 46 | 19 | 43 | 57.5 | 49.5 | 5 |
| DLP (mGy x cm) | | | | | | | | | |
| Head | 758.3 | 665 | 725 | 731 | 386 | 913 | 817 | 587 | 386 |
| Effective Dose (mSv) | | | | | | | | | |
| Head | 1.5 | 1.6 | 1.7 | - | - | 2.1 | 1.6 | - | - |

**Ed. Cambridge University Press, 2002.**

A total of 426 CT scans on adults, and 26 on children were measured for Computed Tomography Dose Index (CTDI) in the air by Abdullah et al. 2009 at Malaysian hospitals. Studies performed for European guidelines, the UK, and Taiwan showed a similar range of effective dosages for routine head, routine chest, and pelvic inspections. The effective doses for routine abdominal inspection were comparable to those found in studies based on European guidelines and Taiwan but 55.1% greater than the value from the analysis performed in the UK. Third-quartile values of effective doses for all CT examinations collected were provided by the study to aid in defining the dosage reference level for CT examinations in Malaysia [35]. Results showed higher CTDI and DLP for CT scans of the brain, chest, and abdomen compared to the UK.

The effective Dose was quantified by Oberg et al., 2007 and used in medical practice. Specifically, they wanted to figure out the ED[36]. The results of this research have the potential to be utilised as the basis for standardised protocols relating to the exposure doses required for routine CT exams of the head, chest, and abdomen.

Mastora et al. (2009) computed the $CTDI_{VOL}$, DLP, and effective Dose and compared those results with the EC[37] for numerous body locations (regular head, cervical spine, belly, and chest inspections). A CT survey found that the average DLP values for adults ranged from (923.2-1394.6) mGy-cm for the brain, (854.7-1517.8) mGy-cm for the neck, and (301.0-1029.1) mGy-cm for the chest (abdomen). The average effective doses for the head, chest, cervical spine and abdomen were 2.47, 7.53, 9.87, 6.20, 9.49, and 15.22 mSv, respectively. The values for the head, chest and abdomen checks were more significant than in this study.

**Table 11: Scan parameters and dose estimates for all scanners in Head Examination**

| Scanner | N | kVp (n) | mAs [median (range)] | Pitch [median (range)] | Slice Thickness (mm) | FOV (cm) | DLP [(mGy X cm) Mean] | ED [(mSv) Mean] | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Male | Female |
| 16 Slice GE Revolution | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 685.86 | 1.59 | 1.24 |
| 16 Slice Siemens Emotion | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 773.66 | 1.70 | 1.46 |
| 16 Slice Philips Brilliance | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 1058.30 | 2.35 | 1.97 |
| 32 Slice Siemens Scope | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 951.10 | 2.14 | 1.82 |
| 08 Slice | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 641.76 | 1. | 1.14 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| GE Revolution ACTs | | | | | | | | 51 | |
| 08 Slice Siemens Emotion | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 976.23 | 1.99 | 2.11 |
| 64 Slice Siemens Somatom | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 943.26 | 2.10 | 1.77 |
| 128 Slice Philips Ingenuity | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 540.00 | 1.27 | 0.93 |
| 64 Slice Toshiba Aquilion | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 555.63 | 1.21 | 1.04 |
| 64 Slice GE VCT | 30 | 100, 200 | 150, 220 | 0.67 (0.2-1.2) | 5 | 18 | 458.10 | 0.93 | 1.01 |

**Table 12: Comparison of $CTDI_{VOL}$, DLP, ED of TUTH with European Commission (EC)**

| **Examination** | | **Mean (TUTH)** | **EC** |
|---|---|---|---|
| **Head** | **$CTDI_{VOL}$ (mGy)** | **-----** | **60** |
| | **DLP (mGy X cm)** | **758.3** | **1050** |
| | **Eff. Dose (mSv)** | **1.5** | **2.4** |

## CONCLUSIONS

The current study's findings highlighted the importance of body weight and gender in DLP-based monitoring of radiation exposure in head CT. The DLP differed across men and women and increased with body weight. The DLP's relationship to sex and weight reflects the imaging process's radiation dosage characteristics. The bias caused by changes in the patient population is decreased by adjusting the DLP for sex and weight, making it easier to compare imaging procedures and scanners. The change makes it easier to detect unexpected differences in radiation exposure.

DLP and ED for the regular head protocol were much lower than the European Commission's recommendation (EC). Even though the DLP and effective dose of the head inspection were lower than the EC, the diagnostic picture quality was unaffected.

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**Conflict of interest**

There is no conflict of interest declared in this article**.**

**Authors Contributions**

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**Availability of Data and Material**

The datasets generated or analysed during the study are available from the corresponding author upon reasonable request.

**References:**

1. Curry, Thomas S., James E. Dowdey, and Robert C. Murry. Christensen's physics of diagnostic radiology. Lippincott Williams & Wilkins, 1990.
2. Dixon, Robert L., Michael T. Munley, and Ersin Bayram. "An improved analytical model for CT dose simulation with a new look at the theory of CT dose." Medical physics 32.12 (2005): 3712-3728.
3. Mathews, J. D. et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. BMJ. 346, f2360 (2013).
4. Pearce, M. S. et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 380(9840), 499–505 (2012).
5. Brenner, D. J. and Hall, E. J. Computed tomography—an increasing source of radiation exposure. N. Engl. J. Med. 357, 2277–f2384 (2007).
6. Goo, H. W. CT radiation dose optimisation and estimation: an update for radiologists. Korean J. Radiol. 13, 1–11 (2012).
7. Lee, T. Y. and Chhem, R. K. Impact of new technologies on dose reduction in CT. Eur. J. Radiol. 76, 28–35 (2010).
8. Duong, P. A. and Little, B. P. Dose tracking and dose auditing in a comprehensive computed tomography dose reduction program. Semin. Ultrasound CT MR. 35, 322–330 (2014).

9. Midgley, S. M. Capture and analysis of radiation dose reports for radiology. Australas. Phys. Eng. Sci. Med. 37, 805–819 (2014).
10. American Association of Physicists in Medicine. The measurement, reporting, and management of radiation dose in CT (Report #96). (2008).
11. Roch, P. and Aubert, B. French diagnostic reference levels in diagnostic radiology computed tomography and nuclear medicine: 2004–2008 review. Radiat. Prot. Dosim. 154, 52–75 (2013).
12. Foley, S. J., McEntee, M. F. and Rainford, L. A. Establishment of CT diagnostic reference levels in Ireland. Br. J. Radiol. 85, 1390–1397 (2012).
13. Treier, R., Aroua, A., Verdun, F. R., Samara, E., Stuessi, A. and Trueb, P. R. Patient doses in CT examinations in Switzerland: implementation of national diagnostic reference levels. Radiat. Prot. Dosim. 142, 244–254 (2010).
14. Shrimpton, P. C., Hillier, M. C., Lewis, M. A. and Dunn, M. National survey of doses from CT in the UK: 2003. Br. J. Radiol. 79, 968–980 (2006).
15. Fukushima, Y., Tsushima, Y., Takei, H., Taketomi, Takahashi, A., Otake, H. and Endo, K. Diagnostic reference level of computed tomography (CT) in Japan. Radiat. Prot. Dosim. 151, 51–57 (2012).
16. ICRP. Managing patient dose in multi-detector computed tomography (MDCT). ICRP Publication 102. Ann. ICRP 37, (2007).
17. Huda, W., Ogden, K. M. and Khorasani, M. R. Converting dose-length product to effective Dose at CT. Radiology. 248, 995–1003 (2008).
18. Lee, C. H., Goo, J. M., Ye, H. J., Ye, S. J., Park, C. M., Chun, E. J. and Im, J. G. Radiation dose modulation techniques in the multidetector CT era: from basics to practice. Radiographics. 28, 1451–1459 (2008).
19. Kalra, M. K., Maher, M. M., Toth, T. L., Schmidt, B., Westerman, B. L., Morgan, H. T. and Saini, S. Techniques and applications of automatic tube current modulation for CT. Radiology. 233, 649–657 (2004).
20. Iball, G. R. and Tout, D. Computed tomography automatic exposure control techniques in 18F-FDG oncology PET-CT scanning. Nucl. Med. Commun. 35, 372–381 (2014).
21. Papadakis, A. E., Perisinakis, K. and Damilakis, J. Automatic exposure control in CT: the effect of patient size, anatomical region and prescribed modulation strength on tube current and image quality. Eur. Radiol. 24, 2520–2531 (2014).
22. Elameen S. Technique and radiation dose in CT examination of adult patients. Master Thesis. Sudan Academy of Sciences (SAS) Atomic Energy Council, 2010, pp 3-23.
23. Abdullah A. Establishing dose reference level for computed tomography (CT) examinations in Malasiya. Master Thesis. Universiti Sains Malaysia, 2009, pp 3-16.
24. Oberg M. Patients doses for CT examinations in Denmark. Master Thesis. Technical University of Denmark, 2011, pp 3-25.
25. Mastora S. Patient dose in common CT. Master Thesis, University of Patras, 2009, pp 5-55.
26. Tsapaki V, Kottou S, Papadimitriou D. Application of European Commission reference dose levels in CT examination in Crete, Greece. Br J Radiol. 2001; 74.
27. Papadimitriou D, Perris A, Manetou A, Molfetas M, Panagiotakis N, Lyra Georgosopoulou M, et al. A survey of 14 computed tomography scanner in Greece and 32 Scanner in Italy:

Examination frequencies, dose reference values, effective doses to the organ. Radiat Prot Dosimetry. 2003; 104: 47-53.

28. Hatziioannou K, Papanastassiou E, Delichas M, Bousbouras P. A contribution to the establishment of diagnostic reference levels in CT. Br J Radiol. 2003; 76: 541-45.
29. Tsai H, Tung C, Yu C, Tyan Y. Survey of computed tomography scanners in Taiwan: Dose descriptors, dose guidance levels and effective doses. Med Physics. 2007; 34: 1234-43.
30. Origgi D, Vigorito S, Villa G, Bellomi M, Tosi G. Survey of computed tomography techniques and absorbed Dose in Italian hospitals: A comparison between two methods to estimate the dose-length product and the effective Dose and to verify fulfilment of the diagnostic reference levels. Eur Radiol. 2006; 16: 227-37.
31. Hiles P, Brennen S, Scott S, Davies J. A survey of patient Dose and image quality for computed tomography scanners in Wales. J Radiol Prot. 2001; 21: 345-54.
32. Ngaile J, Msaki P, Kazema R. Towards the establishment of the national reference dose levels for computed tomography examinations in Tanzania. J Radiol Prot. 2006: 26: 213-25.
33. Clarke J, Cranley K, Robinson J, Smith P, Workman A. Application of draft European Commission reference levels to a regional CT dose survey. Br J Radiol. 2000; 73: 43-50.
34. Hidajat N, Maurer J, Schroder R, Nunnemenn A, Wolf M, Pauli K, et al. Relationships between physical dose quantities and patient Dose in CT. Br.
35. Abdullah A. Establishing dose reference level for computed tomography (CT) examinations in Malasiya. Master Thesis. Universiti Sains Malaysia, 2009, pp 3-16.
36. Oberg M. Patients doses for CT examinations in Denmark. Master Thesis. Technical University of Denmark, 2011, pp 3-25.
37. Mastora S. Patient dose in common CT. Master Thesis, University of Patras, 2009, pp 5-55.