Diagnostic reference levels for adult’s abdominal computed tomography in a referral centre in Nigeria

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Abstract. To address the limitation of CTDIvol, the American Association of Physicists in Medicine recently published a report on SSDE in body CT, where a patient’s size is used to compute an estimate of patient dose from CTDIvol. This study estimates patients’ radiation dose in abdominal computed tomography examination by considering patient size and established a facility diagnostic reference levels (DRLs) based on CTDI, DLP and SSDE for the purpose of dose optimization. A prospective cross-sectional study was carried out at Aminu Kano Teaching Hospital (AKTH), Kano-Northwestern Nigeria from April 2019 to September 2019. The study reviewed Fifty-five patients for abdominal Computed Tomography based on the recommendation of ICRP for DRLs. The study considered CTDIvol, DLP and SSDE. The SSDE is based on the anterior-posterior and lateral diameters of the patients; and a conversion factor (f). Statistical Package for Social Sciences (SPSS) Version 23.0 was used to analysed the mean, median, standard deviation and interquartile range of the radiation dose received. Independent Student t-test was used to determine the relationship between CTDIvol, DLP and SSDE by taking SSDE as an independent variable. The mean and standard deviation values of the estimated SSDE for 18-27, 28-37, 38-47, 48-57, 58-67 and 68-77 patients’ age groups are 12.9, 13.74, 13.22, 13.49, 10.44 and 12.43mGy and 4.15, 5.71, 5.21, 4.05, 3.14 and 5.24 respectively. The established DRL values for CTDI, DLP and SSDE are 11.50, 620.30 and 16.85 respectively. There was no statistical significance difference (P<0.05) between reported CTDI and DLP and the estimated SSDE. There is good optimization of radiation dose in Aminu Kano teaching hospital, with regard to CT abdomen but still patients’ size needs to be considered.

Keywords: Computed Tomography, Radiation, Dose, Optimization, Size-specific

1.Introduction

Computed tomography (CT) has become the major source of population exposure to diagnostic imaging. Optimization measures within the modality are crucial to ensure appropriate use and avoidance of unnecessary radiation exposure. Moreover, the use of CT in medical diagnosis delivers radiation doses to patients that are higher than those from other imaging modalities. CT measurements of radiation dose parameters is one of the quality control measurements, which is used to know the amount of
radiation received by the patient and producing an image of diagnostic value. CT dose parameters such as CT dose index (CTDI), dose length product (DLP), effective dose, and the newly proposed size specific dose estimate (SSDE) are usually used. The CTDIvol is a measure of the intensity of radiation that is used to perform the CT examination, which is independent of the scan length. DLP indicates patients’ total dose received during a complete process of CT scan. The DLP is based on CTDIvol factors in the length of the scan [1][2][3].

To ensure proper monitoring of radiation doses, the International Electrochemical Commission requires all CT scan manufacturers to display radiation dose output with descriptors such as CTDIvol and DLP before and after examination in the form of dose page. One of the major limitations of CTDIvol is that it does not represent the actual patient absorbed doses, as it does not take into account the heterogeneous attenuation and size of individual patients. Recently, the American Association of Physicists in Medicine (AAPM) report 204 [11], has proposed a new method, “size specific dose estimate” (SSDE) to represent more accurate estimations of patient doses. SSDE takes into account patient size in order to enable users to optimize CTDIvol based on patient’s physical dimensions, where a conversion factor is used depending on patients’ size [4][5][6][7].

In medical exposure, the concept of diagnostic reference levels (DRL) was established to identify situations in which the magnitude of the radiation dose is beyond current practice. DRL implemented by European countries to several radiological investigations are a practical tool to promote the assessment of existing protocols by facilitating the comparison of doses from present practice. DRLs were defined by the ICRP in 1996 as being a form of investigation level or test for identifying situations where patient doses are becoming unusually high and local review of procedures and equipment is required. The pragmatic way, recommended by European Commission, to assess DRL values is to use the third quartile values observed in wide scale surveys of typical doses for common procedures [8].

A DRL is a reference level used to identify unusually high or low radiation doses for common diagnostic imaging procedures. DRLs are suggested action levels above which a facility should review its protocols and determine if acceptable image quality can be achieved at lower doses. The International Commission on Radiological Protection (ICRP) emphasizes that DRLs “are not for individual patient’s data or for regulatory or commercial purposes, and also not a dose constraint.” DRLs are based on standard phantom or patient measurements under specific conditions at a number of representative clinical facilities. DRLs for a facility should be set at approximately the 75th percentile of measured patient or phantom data. This means that procedures performed at 75% of the institutions surveyed have exposure levels at or below the DRL [9].

Diagnostic reference levels are not the prescribed dose for a particular procedure or an absolute upper limit for dose. Rather, they represent the dose level at which an investigation of the appropriateness of the dose should be initiated without
compromising with the image quality. The assessment of quality of an image should be carried out by a qualified medical physicist, a radiologist and a Radiographer to determine whether or not the required level of image quality could be attained at lower dose levels[10].

The aim of this study was to estimate patients’ local radiation dose for abdominal computed tomography examination by considering patient size and to establish a facility diagnostic reference levels (DRLs) based on CTDI, DLP and SSDE in our locality and to compare with other published data for the purpose of dose optimization.

2. Materials

The study was carried out using Computed Tomography machine manufactured by Toshiba (Model Aquillon 160slice) and installed in 2015. The machine has automatic exposure control modulation.

3. Methods

This is a prospective cross-sectional study carried out at Muhammadu Sunusi Radio-diagnostic centre of Aminu Kano Teaching Hospital (AKTH), Kano-Nigeria from April 2019 to September, 2019 using a simple random sampling technique. Fifty-five patients were studied based on the recommendation of ICRP for establishment of Diagnostic Reference level. The study comprised all adult patients for abdominal computed tomography. The machine has automatic exposure control modulation. Anatomical information such as age, patient anterior-posterior diameter, lateral diameter (and effective diameter was calculated). CT dose parameters and exposure parameters such as CTDIvol, DLP, Kvp, mAs were also recorded. However, for the SSDE calculation, the effective diameter and CTDIvol were used. Calculating SSDE for each patient: the SSDE is the patient dose estimate by considering correction factors applied to the CTDIvol based on the patient size. Tables with conversion factors (f) for different diameters between 10 and 45 cm were considered.

Data was analysed using statistical package for social sciences (SPSS) version 23. Descriptive statistics such as mean and standard deviation/median and inter-quartile range were calculated. Minimum and maximum values were recorded. Seventy fifth (75th) percentile or (3rd quartile) value of the total median of CTDI, DLP and SSDE for the examinations were also calculated. Independent student t-test was used to determine the correlation between CTDIvol, DLP with SSDE. Level of significance of p=0.05 was used as an indicator at 95% confidence interval.

In line with Helsinki declaration for protection of human participants during research, Institutional Review Board approval (NHREC/21/08/2008/AKTH/EC/2693) was obtained from the health research and ethics committee of Aminu Kano Teaching Hospital Kano-Nigeria.
4. Results

Table 1a summarizes the estimated values of SSDE presented as mean, median values, and standard deviation values. The minimum-maximum SSDE Values were 4.95mGy and 25.58mGy. The mean and median values of the estimated SSDE for 28-37- and 48-57-years age group were the highest representing 13.74mGy and 13.49mGy and 13.95mGy and 14.06mGy respectively.

Table 1b: summarizes the estimated values of CTDI and DLP presented as mean, median and standard deviation values. The minimum-maximum values of CTDI and DLP were 2.70-20.80mGy and 164.50-1042.80cmGy respectively. The highest mean and median values of CTDI and DLP values were 9.85mGy and 9.25mGy, and 496.81cmGy and 472.60cmGy respectively.

Table 2: summarizes the median and the 75th percentile (DRL) of CTDIvol, DLP, and SSDE for abdominal computed tomography in the study. There was no significant difference for median and 75th percentile for CTDIvol, DLP and SSDE thus 8.99mGy and 8.70mGy; 455.61cmGy and 422.50cmGy; and 13.98mGy and 13.46mGy.

Table 3 summarizes the relationship between SSDE and CTDIvol, DLP. SSDE was taken as an independent variable. Critical value is smaller than the t-value in each case, this indicates that no association between SSDE and CTDIvol so also between SSDE and DLP.

Table 4 summarizes the comparison of present study with other published literatures. the CTDIvol and SSDE values were below those obtained in United states and American College of Radiology (ACR). The DLP value is lower than that of United States and higher than that of ACR.

Table 1a: Estimated values of SSDE according to age group in the study.

| AGE GROUP (years) | FREQUENCY | SSDE (mGy) | MIN | MAX | MEAN | MEDIAN | STD |
|------------------|-----------|------------|-----|-----|------|--------|-----|
| 18-27            | 7         | 8.83       | 20.60 | 12.90 | 11.81 | 4.15   |
| 28-37            | 14        | 6.49       | 25.58 | 13.74 | 13.95 | 5.71   |
| 38-47            | 14        | 4.95       | 20.59 | 13.22 | 13.90 | 5.21   |
| 48-57            | 11        | 4.97       | 19.54 | 13.49 | 14.06 | 4.05   |
| 58-67            | 7         | 7.43       | 14.23 | 10.44 | 9.02  | 3.14   |
| 68-77            | 2         | 8.72       | 16.13 | 12.43 | 12.43 | 5.24   |
Table 1b: Estimated values of CTDI and DLP according to age group in the study.

| AGE GROUP (years) | FREQ | CTDIvol (mGy) | DLP (mGycm) |
|-------------------|------|---------------|-------------|
|                   |      | MIN | MAX | MEAN | MEDIAN | STD | MIN | MAX | MEAN | MEDIAN | STD |
| 18-27             | 7    | 4.80| 20.20| 8.83 | 6.90 | 5.25 | 245.20| 1015.90| 442.96| 375.30| 262.48|
| 28-37             | 14   | 3.40| 20.80| 9.85 | 9.25 | 6.09 | 164.50| 1042.80| 496.81| 472.60| 256.10|
| 38-47             | 14   | 3.00| 17.30| 9.18 | 8.90 | 9.18 | 167.90| 1031.90| 480.82| 449.95| 252.74|
| 48-57             | 11   | 2.70| 13.20| 8.79 | 8.80 | 3.09 | 189.60| 1017.70| 493.60| 441.10| 230.08|
| 58-67             | 7    | 4.50| 9.60 | 6.57 | 4.90 | 2.48 | 203.10| 493.70 | 322.39| 234.40| 130.46|
| 68-77             | 2    | 5.10| 12.60| 8.85 | 8.85 | 5.30 | 229.80| 650.50 | 440.15| 440.15| 297.48|

Table 2: Established DRL for CTDI, DLP and SSDE for abdominal CT in the study.

| DOSE PARAMETERS | CTDIvol | DLP | SSDE |
|-----------------|---------|-----|------|
| DRL             | 8.99    | 455.61 | 13.98 |
| MEDIAN          | 8.70    | 422.50 | 13.46 |

Table 2 above shows the median doses received and 75 percentile (DRLs) for computed tomography examination of abdominal CT.

Table 3: Relationship between SSDE and CTDIvol, DLP in the study.

| SSDE-CTDIvol | SSDE-DLP |
|--------------|----------|
| t -VALUE     | 17.92    | -11.03  |
| P-value      | 0.000    | 0.000   |
| CRITICAL VALUE (CV) | 2.57 | 2.57 |
Table 4: Comparison between DRLs of this study with previous literature.

|        | Present study | U.S. DRLs | ACR DRLs |
|--------|---------------|-----------|----------|
| CTDI   | 8.99          | 11.00     | 9.80     |
| DLP    | 455.61        | 524.00    | 418.00   |
| SSDE   | 13.98         | 15        | 16.40    |

5. Discussion

This study was conducted in Aminu Kano Teaching Hospital with 164-slice CT scanner. A total number of 55 patients both males and females were studied. The average number of patients for this study is 4 patients per day in this hospital. The study established diagnostic reference levels for CT examination of abdomen in the hospital.

Table 3 shows a comparison between SSDE and CTDIvol so also between SSDE and DLP. In both cases student t distribution table was used for the comparison. The value (critical value) obtained from the table is 2.57 which is lower than the t value of comparison between SSDE and CTDIvol (17.92). Similarly, the critical value is lower than the t value of comparison between SSDE and DLP (11.03). This shows there is no association between SSDE and CTDIvol, so also between SSDE and DLP.

Although the diagnostic reference levels of U.S. and ACR-AAMP-SPR are established at lateral body diameter of 25-29cm of the adult abdomen studied but both DRLs are higher than the diagnostic reference levels of this work in all aspect except DLP of the ACR-AAMP-SPR which is lower than the DLP of this work. Using student t- distribution table shows that no association between DRLs of this study and the established DRLs of United State and American college of radiology, this investigation revealed an observable change in CT practices, with a much wide range of studies being performed regularly. This reflects the improved capacity of CT scanners to scan longer distances and at fine resolutions as permitted by helical and multi slice technology as reported [11].

6. Conclusion and Recommendation

The DRL established in this study is lower when compared with other reported international values. This study shows that there is good optimization of practice in CT in Aminu Kano Teaching Hospital, with regard to CT abdomen. Patient specific size should be considered so as to improve optimization technique for abdominal CT examination in AKTH.
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