**DIAGNOSTIC REFERENCE LEVELS FOR ABDOMINAL COMPUTED TOMOGRAPHY EXAMINATIONS IN A SOUTH EASTERN STATE, NIGERIA**

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**ABSTRACT**

**Background:** The use of diagnostic reference levels has been shown to reduce the overall dose and the range of doses observed in clinical practice. Optimization of patient dose in computed tomography requires the application of examination-specific scan protocols tailored to patient age, size, region of body and clinical indication.

**Objectives:** To establish the computed tomography dose index (CTDI) and Dose length product (DLP) for abdominal CT examinations in Anambra State and to ascertain the level of compliance of current practice with respect to the internationally established (DRLs) as well as the effective dose values for abdominal CT examinations.

**Method:** A total of 60 adult subjects presented for abdomen examinations from each of the four CT centres with a total of 240 subjects were surveyed for over a 6-month period**.** Data were obtained from a GE Brightspeed multidetector CT scanners, Toshiba Alexium and Siemens somaton perspective. The dose were derived from computed tomography dose index (CTDI vol), and dose length product (DLP) with the effective dose (E) calculated. Data was analyzed using SPSS version 20 software and 75th percentile of DLP and CTDIvol were adopted as a basis for DRLs.

**Results:** The 75th percentile values for CTDIvol and DLP were 24mGy and 962.8 mGy/cm for abdomen. The calculated effective dose value is 14.4mSv.

**Conclusion:** Dose variations across CT centres have identified an urgent need for optimization tobring down centre-specific and composite DRL in tandem with works done abroad

**Keywords:** Dose optimization, Computed Tomography, Diagnostic Reference Levels

**INTRODUCTION**

A Computed Tomography (CT) scan also called X-ray CT scan is an imaging modality with non-invasive method of acquiring detailed images of the structures inside the human body without overlap of overlying anatomical structures.[1,8] .

CT scan is recognized as the largest contributor to population doses from medical exposure [11] with CT examinations of chest and abdomen is currently increasing due to technological advancement which allow scanning of large area including the radiosensitive organs of the body [12].

In Ireland, chest and abdominal CT examination account for 20% of all CT studies and result in absorbed doses of up to 20mGy, which is highest in diagnostic Radiology.7 Excessive doses in CT are not as readily identified through image quality effect as in conventional radiography, thus an awareness of typical dose level allows CT Radiographers to quickly identify and address any unjustified radiation dose [42]

The use of diagnostic reference levels has been shown to reduce the overall dose and the range of doses observed in clinical practice. For example, U.K national dose surveys demonstrated a 30% decrease in typical radiographic doses from 1984 to 1995 and an average drop of about 50% between 1985 and 2000 [16].

Optimization of patient dose in computed tomography requires the application of examination-specific scan protocols tailored to patient age, size, region of body and clinical indication in order to ensure that the dose to each patient is as low as reasonably practicable for the clinical purpose of the CT examination. 5 Three fundamental principles of radiation protection were approved by International Commission on Radiological Protection (ICRP). They include justification, optimization and dose limitation.  The principle of justification requires that any decision that involves the use of ionizing radiation source should result in sufficient individual or societal benefit to offset the detriment it causes [21]. In addition, as part of the optimization procedure, the ICRP recommends that there should be restriction on the doses to individuals from a particular source and this leads to the concept of dose constraints [21]. Diagnostic reference levels is a tool to ensure that procedures are optimized and remain optimized by continuous improvement of procedures and evaluation of performance of examination. In other words, they are practical tools to promote the assessment of existing protocols and appropriate development of new and improved protocols at each CT centre by facilitating the comparison of doses from present practice should be put in place. It is intended to provide guidance on what is achievable with current good practice rather than optimum. It is defined by Council of the European Union as Dose levels in medical, radio-diagnostic practices or, in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied [26]. The International Commission on Radiological Protection (ICRP) recommends the establishment of diagnostic reference levels as a medium for optimizing the radiation dose delivered to patients in the course of diagnostic procedure. The dosimetric parameters recommended for monitoring the DRL in CT examination are weighted Computed Tomography Dose Index (CTDIvol) and Dose Length Product (DLP)[13]. DRLs are usually calculated by collection of patient dose data at the 75th percentile point of the dose spread (CTDIw. and DLP)[32]

International Atomic Energy Agency (IAEA) requires every country to establish a   radiation regulatory body. Consequently, Nigerian Nuclear Regulatory Authority (NNRA) and National Institute for Radiation Protection and Research (NIRPR) in 1996 and 2005were respectively established by Act 19 of 1995. These two bodies are responsible for research, regulating and training of Radiation Protection Personnel (RPP) in Nigeria as well as establishment of national, regional and local diagnostic reference levels [35].

**MATERIALS AND METHODS**

A prospective cross sectional design was adopted during this study. The study was carried out in four CT for a period of six month. Using a purposive sampling technique the population of this study included all prospective adult subjects for CT abdominal examinations in four CT centres in the state. For establishment of Diagnostic Reference Levels DRLs, a minimum of 10 participants is recruited for each body part under examination. 13 In several reviewed studies, a minimum of 10 patients for each body region was considered significant in establishment of diagnostic reference levels. 39, 3 Adult patients from 18 years and above referred and patients who presented for routine CT examination were considered in this study. Ethical approval was obtained from the hospitals studied. Data were obtained with the aid of a data capture sheet adopted from the IAEA survey form and has the following sections: participant demographic information, scan parameters and dosimetric quantities and parameters through the assistance of CT Radiographers in charge of the four centres surveyed. The demographic information considered in this study were gender, age, and body region. Data was analyzed using SPSS version 20.0 Chicago. The mean, standard deviation and 75th percentile (third quartile) values were used. Comparison was made between the measured doses and reported data from the European (DRLs) have been established. Statistically significant results of dose values between CT centres were determined at 0.05 level of significance.

**RESULTS**

**Table** 1: **Age, gender and number of subjects**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| CT Centres | Frequency | | Total | Range (years) | Mean ± SD (years) |
| **Male** | **Female** |
| Centre A | 30 | 30 | 60 | 18 - 80 | 51 ± 16.4 |
| Centre B | 33 | 27 | 60 | 18 - 79 | 45 ± 16.3 |
| Centre C | 31 | 29 | 60 | 19 - 80 | 54 ± 16.2 |
| Centre D | 27 | 33 | 60 | 25 - 79 | 50 ± 14.3 |
| Composite values. | 121 | 119 | 240 | 18 - 80 | 50 ± 16.1 |

**Table 2: Mean and 75th percentile of the CTDIvol and DLP**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | Abdomen CTDIvol | | Abdomen (mGy-cm) DLP | |
| Mean | 75th percentile | Mean | 75th percentile | |
| Centre A | 22.0 ± 20.6 | 24.3 | 717.7 ± 177.4 | 818.5 | |
| Centre B | 28.1 ± 48.0 | 16.2 | 938.0 ± 425.3 | 1102.0 | |
| Centre C | 31.5 ± 41.1 | 34.1 | 677.4 ± 339.0 | 943.8 | |
| Centre D | 16.1 ± 10.0 | 20.0 | 706.7 ± 260.5 | 966.0 | |
| Composite values. | 24.6 ± 33.7 | 24.0 | 758.5 ± 327.1 | 962.8 | |

**Table 3: The 75th percentile of the CTDIvol and DLP according to gender**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | CTDIvol (mGy | | DLP (mGy/cm) | |
| Male | Female | Male | Female |
| Centre A | 29.0 | 21.0 | 812.0 | 886.0 |
| Centre B | 16.0 | 16.4 | 1062.0 | 1600.0 |
| Centre C | 60.0 | 29.0 | 1047.3 | 959.0 |
| Centre D | 26.0 | 17.6 | 944.0 | 953.0 |
| Composite values | 27.1 | 17.6 | 954.2 | 966.0 |

**Table 4: Effective dose values for chest and abdominal CT in Anambra state**

|  |  |
| --- | --- |
| Body Region | Abdomen |
| DLP | 926mGy.cm |
| Effective Dose | 14.4mSv |

**Table 5: Comparison of present work with some published European  DRL values**

|  |  |  |  |
| --- | --- | --- | --- |
| Research Study | Location | Abdomen | |
| CTDI (mGy) | DLP (mGy-cm) |
| Present study, 2016 | Nigeria | 24 | 963 |
| European Commission,1999 | UK | 35 | 780 |
| ARPANSA, 2015 | Australia | 15 | 700 |
| [Saravanakumar](http://www.ncbi.nlm.nih.gov/pubmed/?term=Saravanakumar%20A%5Bauth%5D), 2015 | India | 16 | 482 |
| JARPM, 2015 | Japan | 20 | 1000 |
| Bourguignone, 2008 | France | 15 | 921 |
| Maximum % deviation | Nigeria with | UK: 31.4 % | Japan: 3.7 % |

**Table 6: Correlation of anthropometric variables with CTDIvol and DLP**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables |  | CTDI | DLP | Remark |
| age | **r** | -0.037 | -0.038 | Poor correlation |
| **p** | 0.685 | 0.684 | Not significant |

**DISCUSSION**

From our study, the 75th percentile for the CTDIvol and DLP results were 24 mGy and 963 mGy.cm for abdomen. These values were higher than the values published for adult Abdomen in Australia and approximately 37.5% for CTDIvol (15mGy) / approximately 27% for DLP (700 mGy·cm) for abdomen. The values are also higher when compared to the published values for abdomen in India by approximately 33% for CTDIvol (16mGy) and approximately 50 % for DLP (482 mGy·cm) for abdomen [3].

Also our study recorded values lower than those generated in Ibadan western Nigeria by approximately 36.7% for CTDIvol (24mGy)/approximately double the DLP (962.8mGycm) for abdomen [24]. Similarly, our generated value were also lower than values obtained at Maiduguri, Northern Nigeria for abdomen by approximately 27.1% for CTDIvol (24mGy) and approximately 42.6% for DLP (962.8mGy.cm) [1].

In other to ascertain the level of compliance of current practices in  similar research findings in the literature, further comparisms were made From our work, the CTDIvol for abdomen (24 mGy) fall within the   range    found in the literature for abdomen (15–35mGy) respectively. 13, 3, 6 However, the DLP for abdomen (963 mGy-cm) was    within the    range found in the literature (482 – 1000 mGy-cm) [13, 6, 4, 39].

Also, inter-centers comparisons with regard to the proposed DRL from the study were made. From the analysis, we noted that almost 50% of CT centres that participated in this study exceeded the DLP set for the DRL. Also, 75 % of the values for chest and 50% for abdomen exceeded the CTDI Vol proposed for the state. This indicates that there is urgent need for dose audit and optimization measures.

 DLP was converted to effective dose using a normalized coefficient found in the European guideline 0.015 mSv.mGy¯1 for abdominal CT. The mean effective dose value for abdominal CT was 14.4mSv. These values are higher than values obtained in UK, 13.3 mSv, Australia, 11.9 mSv and India 8.2 mSv for abdomen respectively. [13, 6].

 Age had a weak negative correlation with CTDIvol for abdomen (r = - 0.037, p = 0.685) at p-values > 0.05 level of significance. Also, age also correlate negatively with abdomen (r = -0.338, p = 0.684) at p-values > 0.05 level of significance. This indicates that there is no correlations between age and dose (CTDIvol and DLP) for abdominal computed tomography examination and statistically insignificant.

**CONCLUSION**

The CT reference dose level for abdominal examination was found to be CTDIvol 24 mGy for abdomen and DLP 962.8 mGy.cm. From this study, few CT centres met with the international recommended reference levels. However, most centres were not observing proper dose optimization strategies in some cases. The effective dose value for abdominal CT examinations is 14.4 mSv. There was no correlations between age and dose (CTDIvol and DLP) for abdominal computed tomography examination and statistically insignificant.

**REFERENCES**

1. Abdullahi, M., Shittu, H.., Arabisola, A., Eshiett, P., Richard, I., Kpaku, G and Dlama ZJ. Diagnostic Reference Level for Adult Brain Computed Tomography Scans: A case study of a Tertiary Health Care Center in Nigeria. *IOSR Journal of Dental and Medical Sciences. (IOSR-JDMS);* 2015,14 1 (2): 66-75.
2. Aroua, A., Samara, E., Bochud, FO., Meuli, R., & Verdun, FR. Exposure of the Swiss Population to Computed Tomography. *BMC Medical Imaging*, 2013,13:22.
3. ARPNSA RPS 14 (2014). Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation. National Diagnostic Reference Levels Fact Sheet. *A publication of Australian Radiation Protection and Nuclear Safety Agency, Yallambie*.2014.
4. ARPNSA, RPS 14.1 (2008). Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation. National Diagnostic Reference Levels Fact Sheet. *A publication of Australian Radiation Protection and Nuclear Safety Agency, Yallambie*.2008.
5. Boone, JM. The trouble with CTDI 100. Med Physics; 2011,34(4) 311–316.
6. Bourguignone, MH (2008). Diagnostic Reference Levels in Medical Practice. French Nuclear Safety Authority.
7. Brix G, Nagel HD, Stamm G, Veit R, Lechel U,Griebel J, Galanski. Radiation exposure in multi slice versus single slice spiral CT: result of a nationwide survey. *Europian Radiology* ,2003. 13 (8) 1979-1991.
8. Buzug, TM. (2008). Computed Tomography: From Photon Statistics to Modern Cone-Beam CT. Berlin Germany: Springer-Verlag Heildelberg. 86-92.
9. Bushberg, JT, Anthony, J, Edwin, M, John, M, & Boone JM. (2002). Essential physics of medical imaging. 6th Edn. Philadelphia: Lippincott Williams & Wilkins. Pp. 9 *-*34.
10. Carter, C.E. & Veal, B.L. (2008). *Digital Radiography and PACS*. Philadelphia, (PA) USA: Mosby Elsevier. Pp 198-199.
11. Colgan PA, Organo C, Hone C, Fenton D (2008). Radiation dose received by the Irish population. Radiological Protection Institute of Ireland Publication 08/01.
12. European Commission. Council Directive 97/43/Euratom of June 30, 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure. *Off J Eurommun* 1997;L180:22–27.http://eur-lex.europa.eu/legal-content/EN/TXT/?uri= CELEX: 31997L0043.
13. European Commission. (1999). *Guidance on Diagnostic Reference Levels (DRLs) for Medical Exposures.* Radiation Protection 109.
14. Goldman, LW. Principles of CT: Radiation Dose and Image Quality. *Journal of Nuclear Medicine Technology*, 2007,35: 213–225.
15. Graham, H & Frances, A. (1992). *Medical Physics for Advanced Level*. Simon and Schuster Education Campus 400, Maylands Avenue Hemel Herts. P 612- 641.
16. Hart, D, Hillier, MC & Wall, B. (2010). *Doses to Patients from Medical X-ray Examinations in the UK*, NRPB-W14- Chilton.
17. Hart, D & Wall, BF. U.K. Population Dose from Medical X-ray Examinations. *European Journal of Radiology.*2004,76:. 301-309*.*
18. Lewis, MA & Edyvean, S. Patient Dose Reduction in CT. *The British Journal of Radiology,* 2005,78: 880–883.
19. International Atomic Energy Agency (2010). Training course series No. 42 - Radiation biology: A hand book for teacher and students-issn 1018- 5518-Vienna
20. International Atomic Energy Agency TECDOC (2009). Dose Reduction in CT while Maintaining Diagnostic Confidence: A feasibility/demonstration study, Radiation Safety and Monitoring Section.IAEA Vienna International Centre, 1400 Vienna Austria. Available at:http://www.pub.iaea.org/mtcd
21. International Commission on Radiological Protection, (2001) Diagnostic reference levels in medical imaging: review and additional advice. Ann ICRP 31 (4): 33-52.
22. International Commission on Radiological Protection (1996). Radiological Protection and Safety in Medicine. Bethesda, Md; ICRP Report 26; Publication 73.
23. International Electrotechnical Commission (2002). Medical Electrical Equipment. Part 2– 44: Particular requirements for the safety of x-ray equipment for computed tomography. 2.1. International Electrotechnical Commission (IEC) Central Office; Geneva, Switzerland: IEC publication No. 60601.p. 2–44.
24. Institute of Physics and Engineering in Medicine (2004). Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X- Ray Examinations. I.P.E.M, report 88.
25. Japan Association on Radiological Protection in Medicine. [www.radher.jp/j-RIME/report/DRLhoukokusyoEng](http://www.radher.jp/j-RIME/report/DRLhoukokusyoEng). Accessed on 23/02/16
26. Jaska, S, Geofrey, K, Mark, A & Jedidah, M. Patients Radiation Exposure during general fluoroscopy examination. *Journal of applied clinical Medical Physics;* 2013,15(2): 1-10.
27. Kalra, MK, Maher, MM, Toth, TL, Hamberg, LM, Blake, MA, Shepard, J & Saini, S. Strategies for CT Radiation Dose Optimization. *Radiology*, 2004,230: 619-628.
28. Koller, CJ, Eatough, JP & Bettridge, A. Variations in Radiation Dose between the Same Model of Multislice CT scanners at Different Hospitals. *The British* *Journal of Radiology*, 2003,76: 798–802.
29. Lewis, M. (2005). Radiation Dose Issues in Multi-slice CT Scanning, ImPACT technology update no. 3. Available at:http://www.impactscan.org/msctdose.htm
30. Ling (2009). Factors Affecting Image Quality and Radiation Dose in MDCT. PPT. Available at: http//www.gehealthcare.com (18/03/2016)
31. Morin, RL, Gerber, TC & Mc Collough, CH. (2003). Radiation Dose in Computed Tomography of the Heart. *Circulation*, 107: 917-922. Available at: <http://www.circ.ahajournals.org>
32. Mould R. (1998). Introductory Medical Statistics 3rd ed. Bristol: IoP publishing Ltd. Pp 66.
33. Ngaile, JE & Msaki PK. Estimation of Patient Organ Doses from CT Examinations in Tanzania. *Journal of Applied Clinical Medical Physics*, 2006,7(3): 80-94.
34. [Ogbole](http://www.wajradiology.org/searchresult.asp?search=&author=Godwin+I+Ogbole&journal=Y&but_search=Search&entries=10&pg=1&s=0), G & [Obed](http://www.wajradiology.org/searchresult.asp?search=&author=Rachel+Obed&journal=Y&but_search=Search&entries=10&pg=1&s=0), R. Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria. *West African journal of radiology*, 2004, 21: 1-6.
35. Olowookore, CJ, Babalola, IA, Jubiri, NN, Obed RI & Bamidele L. A preliminary Radiation Dose Audit in some Nigerian hospitals: Need for determination of National Diagnostic Reference Level (NDRLs). *Pacific Journal of science and technology,* 2012, 13 (1): 4-6.
36. Olerud HM .Analysis of factors influencing patient doses from CT in Norway. Radiant Prot Dosimetry;1997, 71: 123-33.
37. Rehani, MM & Berry, M. Radiation doses in computed tomography. The increasing doses of radiation need to be controlled BMJ; 2000,320:593–4.
38. Santos, J, Foley, S, Paulo, G, McEntee, MF & Rainford, L. The Establishment of Computed Tomography Diagnostic Reference Levels in  Portugal. *Journal of Radiation Protection Dosimetry*, 2012 ;1-11 .doi:  101093/rpd/nct226.
39. [Saravanakumar](http://www.ncbi.nlm.nih.gov/pubmed/?term=Saravanakumar%20A%5Bauth%5D) A, [Vaideki](http://www.ncbi.nlm.nih.gov/pubmed/?term=Vaideki%20K%5Bauth%5D) KA, [Govindarajan](http://www.ncbi.nlm.nih.gov/pubmed/?term=Govindarajan%20KN%5Bauth%5D) KN, and  [Jayakumar](http://www.ncbi.nlm.nih.gov/pubmed/?term=Jayakumar%20S%5Bauth%5D) S. Establishment of diagnostic reference levels in computed tomography for select procedures in Pudhuchery, India. *Journal of Medical Physics,* 2014,39(1):50–55.
40. Seeram, E. (2000). Computed Tomography: Physical Principle, Clinical Application and Quality Control. 2nd ed. *Toronto*: W.B Saunders P. 430.
41. Shrimpton, PC, Jessen, KA & Panzer, W. (1999). EUR 16262: European Guidelines on Quality Criteria for Computed Tomography. Paper presented  at: Office for Official Publications of the European Communities;  Luxembourg.
42. Shrimpton, PC, Jones GD, Hillier MC, Wall BF, LeHeron JC, Faulkner K (1991). Survey of Computed Tomography practice in the UK. Part 2: dosimetric aspect, NRPB R249.Chilton: NRPB
43. Shope, TB, Gagne, RM & Johnson, GC. A method for describing the doses delivered by transmission x-ray computed tomography. Med Phys; 1981,8 (4): 488–495.
44. Smith, AB, Dillon, WP, Gould, R & Wintermark, M. Radiation Dose Reduction Strategies for Neuroradiology CT Protocols. *American Journal of* *Neuroradiology,*2007,28:1628 –32. Available at: http://www.ajnr.org
45. Treier, A, Aroua, A, Verdun, FR, Samara, E, Stuessi, A & Trueb, PR. Patient doses in CT Examinations in Switzerland: Implementation of National Diagnostic Reference Levels. *Journal of Radiation Protection Dosimetry,*2007 142(2–4), 244–254.
46. Wall, BF & Hart, D. Revised Radiation Doses for Typical X-ray Examinations .*The British Journal of Radiology*, 2007,70:437-439.
47. Willis, J. (2004). *Data Analysis and Presentation Skills: An Introduction for the Life and Medical Sciences.* West Sussex: John Wiley & Sons Ltd. P. 66
48. Yates, SJ, Pike, LC & Goldstone, KE. Effect of Multislice Scanners on Patient Dose from Routine CT Examinations in East Anglia. *The British Journal of Radiology*,2004, 77: 472–478.