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NIGERIAN RADIOGRAPHERS OBLIGATION TO DIAGNOSTIC REFERENCE LEVELS (DRLs) IN MEDICAL IMAGING

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ABSTRACT

Background
Diagnostic reference levels (DRLs) help to identify unusually high dose levels in medical procedures involving radiation. This will subsequently, stimulate quality control. There are legislations and guidelines requiring Member States of European Union to adopt DRLs. While about 72% of European countries as well as the United States have complied, and with subsequent reviews demonstrating significant dose reductions (16% – 30%), no evidences link any African country to replicating the same.

Objective
This work briefly reviewed the progress of Nigeria with regards to diagnostic reference levels (DRLs) and with particular attention to efforts by radiographers.

Methods
Google search was made with keywords of 'diagnostic reference levels' as well as 'radiation dose in Nigeria.' Over forty works were retrieved but only twenty-two which had specific relevance to the focus of the review were archived and read. The works were subsequently scrutinized to piece together the trend of DRLs globally, and locally.

Results
Publications on x-ray, mammography, fluoroscopy and computed tomography dose abound in Nigeria. Doses had wide variations in all modalities. There were no accessible evidence to indicate that any regulatory agency in Nigeria had keyed into the imperative of dose investigation, monitoring and reporting.

Conclusion
In conclusion, diagnostic reference levels in x-ray, mammography and computed tomography have been recommended by independent researchers in Nigeria. Regulatory agencies are urged to summon the will to give guidelines on implementation of these DRLs in order to improve optimization of protection for patients.

BACKGROUND

Medical imaging of the patient is an intricate synergy between hardware, software and humanware [1]. Radiographers are foremost stakeholders in the humanware component who in turn, determine the operational latitude of the remaining two components. Modalities that are new, of latest model, upgraded, or sophisticated, do not necessarily guarantee reduction in radiation dose. No. Only the humanware who is dose - conscious, and who exhibits the twin qualities of compassion and precision, will [2].

Implementation of dose safeguards to exert ethical and moral obligations on such practitioners, is making 'assurance doubly sure' as Shakespeare would say.

Medical imaging is an exercise in compromise. That compromise entails that images of optimum resolution are generated with doses that are 'as low as reasonably achievable (ALARA)' [3]. This compromise is needful due to the stark reality that excessive dose could induce tissue reactions (deterministic/non-stochastic effects) while a combination of excessive and suboptimal dose could increase the risks of stochastic/non-deterministic effects (gene mutation and carcinogenesis) [4]. However, while images have objective criteria for evaluation, ALARA principle is subjective as it does not necessarily mean the lowest radiation dose [3]. Subjectivity is deemed unscientific, and the relevance of ALARA principle is currently being challenged in some quarters [5].

Unless there is a definite benchmark, the word 'low' in ALARA principle will remain amorphous and arbitrary. To reduce arbitrariness in administration of radiation dose for similar populations, modalities, trainings, and practice, the International Commission on Radiological Protection (ICRP) conceptualized, and advocated for the implementation of safeguards for the three categories of persons at risk of medical irradiation; (public) bystanders, (occupational) personnel, and (medical) patients [6, 7, 8].

CONCEPT OF EXPOSURE PARAMETERS AND DOSE

Dose and exposure parameters are neither the same nor used interchangeably. Exposure parameters are the building blocks of an imaging protocol. Dose (mGy) is the end product of the manipulation of exposure parameters (mGy). While exposure parameters can be visually accessed and manipulated on control consoles, dose needs detachable or inherent dosimeters to unmask its quantity. Thermoluminescent dosimeter (TLD) is one of such detachable tools. Furthermore, inherent dosimeters give outputs in dosimetric quantities specific to each modality. Some dosimetric quantities are: dose-area-product, $mGy.cm^2$ (fluoroscopy is), mean glandular dose, mGy (mammography), and volumetric computed tomography dose index, $CTDI_{vol}$ (mGy) and dose-length product, DLP (mGy.cm) for computed tomography [2, 9].

Irrespective of the modality and type of dosimeter used, the common index for stochastic risk assessment is effective dose, ED (mSv). This is calculated from dosimetric quantity of any modality, with the aid of weighting factors from radiation and tissue, which are supplied by ICRP. Safeguards in radiation protection are most commonly set using modality-specific dosimetric quantities and effective dose, ED [10]. Common safeguards are dose constraints using ED (bystanders and personnel), dose limits using ED (bystanders and personnel), and diagnostic reference levels (DRLs) using specific dose quantities (for patients) [7].

DIAGNOSTIC REFERENCE LEVELS FOR PATIENTS

Diagnostic reference levels (DRLs) were conceptualized by ICRP as a result of wide variations in patient dose levels for the same radiographic examinations. At inception of the concept in 1991, it was called 'investigation levels', from whence it morphed into DRLs in 1996. Diagnostic reference level (DRL) is defined as a form of investigation level to identify unusually high dose levels, which calls for reviews, if consistently exceeded. Unlike dose limits for occupational and public exposures which should not be exceeded, DRLs for patients are advisory, and may be exceeded, if it will improve diagnosis. When it is consistently exceeded however, it calls for specific quality control [6, 11].

Currently, there are legislations and guidelines requiring Member States of European Union to adopt DRLs [6, 12]. As a corollary, about 72% of European countries as well as the United States have established DRLs for some radiological examinations and subsequent reviews have demonstrated significant dose reductions (16%–30%) [8, 13], such evidences are difficult to come by in Africa. Only about eight out of fifty-four countries in Africa (15 %) have publications on DRLs, with no evidence linking any country to national DRLs [14]. Regulatory agencies have dual obligations with regards to the issue in focus. First, they are required to adopt values from local publications or to commission a committee to come up with recommendations on DRLs. Second, they are to see that each facility has a radiation safety officer (RSO) who monitors compliance to these advisory safeguards.

To derive DRLs, 75th percentile (3rd quartile) of median doses of representative patients, from representative population, and from representative facilities is used. Homogeneity of subjects in terms of body habitus and radiosensitivity is a major consideration in establishing DRLS. To that effect, there are age (paediatrics and adults) and weight (70 ± 10 kg) bands. There are some other (subtle) considerations too. For example, while weight may have significant correlation with abdominal DRLs, that of the head is not obvious. So, for determining head DRLs, weight consideration may be unnecessary. Other necessarily criteria include; normal anatomic presentations, diagnostic quality of images, calibration status of machine, minimum recommended filtration (x-ray and mammography), et cetera [15, 16, 17].

The International Atomic Energy Agency (IAEA) further recommended 'guidance doses'. This includes DRLs which is an upper bound and 'action level', a lower bound. Action level was given as the 10th percentile of dose distribution at which to initiate an evaluation of image quality. This is premised on the fact that radiation doses that are substantially lower than expected may be associated with poor image quality or inadequate diagnostic information [18].

Table 1: Range of diagnostic reference levels (DRLs) globally and in Nigeria

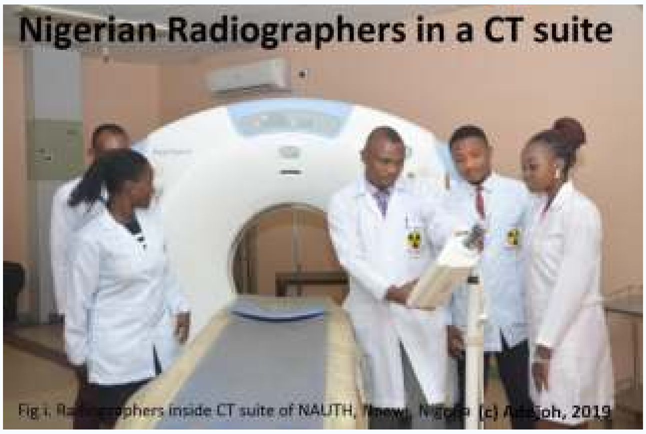
Modality	Anatomic region	Dosimetric quantity	Non- Nigerian range	Nigerian range	Author recommended DRLs for Nigeria
Computed tomography	Head (adult)	$CTDI_{vol}$ (mGy)	10 – 95	8 - 100	64
		DLP (mGy.cm)	100 – 1880	450 – 4585	1200
	Head (paediatrics)	$CTDI_{vol}$ (mGy)	10 - 70	20 - 92	32
		DLP (mGy.cm)	270 - 1620	100 – 4072	600
	Chest (adult)	$CTDI_{vol}$ (mGy)	4 - 90	4 - 109	30
		DLP (mGy.cm)	120 - 1510	265 – 9730	700
	Chest (paediatrics)	$CTDI_{vol}$ (mGy)	15 - 50		15
		DLP (mGy.cm)	200 - 700		350
	Abdomen (adult)	$CTDI_{vol}$ (mGy)	5 - 31	7 - 204	50
		DLP (mGy.cm)	200 - 1423	416 – 4466	800
	Abdomen (paediatrics)	$CTDI_{vol}$ (mGy)	20 - 30		25
		DLP (mGy.cm)	170 - 800		400
X-Ray (adult)	Head (mGy)	ESD (Skull)	1.0 – 6.00	3.0 - 8.80	
		ESD (Dental)	0.25 – 7.0		
	Chest (mGy)	ESD	0.15 – 4.00	0.1 – 6.5	
	Abdomen (mGy)	ESD	2.50 – 10.30	1.4 – 91.0	
	Pelvis (mGy)	ESD	4.00 – 10.00		
	Spine (mGy)	ESD	5.00 – 40.00		
	Extremities	ESD	0.25 – 1.00		
Mammography	mGy	MGD (CC & MLO)	1.50 – 10.00	0.02 – 8.59	
Fluoroscopy	$mGy.cm^2$	DAP	1.00 – 60.00		
Nuclear Medicine	MBq	Activity (Bone)	400 - 750		
		Activity (Liver-spleen)	40 - 150		
		Activity (Lung)	100 - 200		
		Activity (Renal)	40 - 350		

Reference: [2, 8, 13 – 19, 21 – 22]

DIAGNOSTIC REFERENCE LEVEL IN COMPUTED TOMOGRAPHY

Computed tomography modality in Nigeria has steadily increased in number over the years. From a single installation at University College Hospital, Ibadan in 1987, current statistics put the figure at ≥ 175 (2017), ≥183 (2018), ≥ 200 (2020) [19]. While this progress will improve access to this modern diagnostic imaging tool, it is not exactly so in terms of radiation protection due to its known excessive radiation output and inevitable increase in collective effective dose (man sievert) and per caput effective dose (mSv). Computed tomography currently contributes atleast 42 % to the global collective effective dose from medical procedures [20]. A practical idea of the enormity of CT dose is given by Rajiv Ghurye, et. al., 2016 (https://www.gponline.com/diagnostic-imaging-cancer-risk/article/1393464),

"A CT scan of the head equates to 90 chest x-rays, CT of the abdomen equates to 370 chest X-rays, and a CT scan of the chest equates to 440 chest X-rays." It is therefore, imperative that establishment and implementation of DRLs should begin with CT.



FEEDBACK FROM THE FIRST NIGERIAN CT DOSE SURVEY

Three independently-funded nationwide surveys of CT facilities and dose were carried out by Nigerian radiographers from 2017 – 2018 [8, 19, 21]. A summary of findings from those surveys are presented hereinunder:

1. As at 2018, Nigeria had ≥ 183 CT scanners installed with 57.4% (n = 105) owned by private investors. Southern Nigeria had far more scanners (n = 116; 63.4 %) than the North and FCT (n = 67; 36.6%) combined. Whereas, every State in southern Nigeria had at least a CT scanner, three States in northern Nigeria had none. Many of the scanners (83%, n = 151) were functional. Brands of scanners available in Nigeria were General Electric (GE), Toshiba, Philips, Siemens, Neusoft and CereTom and with slice capacity ranging from 1 to 640. As an addendum, as at October 2020, the total number of CT scanners in Nigeria was ≥ 200.

2. Computed tomography dose had wide variations between states and geopolitical zones of Nigeria. The adult CTDIvol (mGy) / DLP (mGy.cm) had a range of 8 – 100 / 450 - 4585 (head), 4 – 109 / 265 - 9730 (chest), and 7 – 204 / 416 – 4466 (abdomen). Paediatric CT dose followed a similar pattern (Table 1). This suggests that there may be no DRLs available or that regulatory oversight may be lacking.

3. There were statistically non-significant ($p > 0.05$) differences between adult and paediatric doses in CT. Closer scrutiny revealed a disturbing finding of higher DLP for paediatrics ≥ 5 years (1493 – 1824 mGy.cm) compared to adults (1310 mGy.cm). The inference is that wrongly programmed protocols were used or that some radiographers were only interested in image quality at the expense of dose optimization.

4. Nigerian CT dose values were often higher than that gleaned from the literature. In addition, the variations in dose output between similar brand of scanners in different centres in Nigeria and between geopolitical zones was excessive (up to 67 % difference in some instances). Inappropriate preset protocols and poor understanding of dose optimization strategies in CT may largely account for this.

5. There were non - radiographers (non-medical persons) with no allegiance to Radiographers Registration Board of Nigeria (RRBN) operating CT scanners all over Nigeria. Furthermore, some CT scanners did not have inherent dosimeters, as a result, patient doses were neither recorded nor known. For CT scanners, this is gross technical error on the part of installation engineers, and should be deemed a misconduct, if deliberate.

6. A scrutiny of head CT protocols in some facilities revealed the following logic(al) flaws: excessive scan range (≥ 150 mm), <1 helical pitch, >1 second gantry rotation time, absence of gap (mm), erratic manual mA manipulation, automatic tube current modulation (auto mA) with high upper threshold, fixed tube potential of 140 kVp, wrong configuration of slices per rotation capabilities, cantho – meatal - line - gantry tilt – mismatch (CMLGM), and neglect of prospective dose

advice. Some postero - anterior (PA) scanograms were also wrongly acquired at an azimuth of zero degree supine (antero-posterior) rather than 90 (lateral) and 180 degree (PA) supine.

7. CT Series were multiplied at the behest of radiologists or requesting physicians which raised the DLP considerably. Interestingly, some CT radiographers did not know anything about 'series 999' and could also not interpret its output.

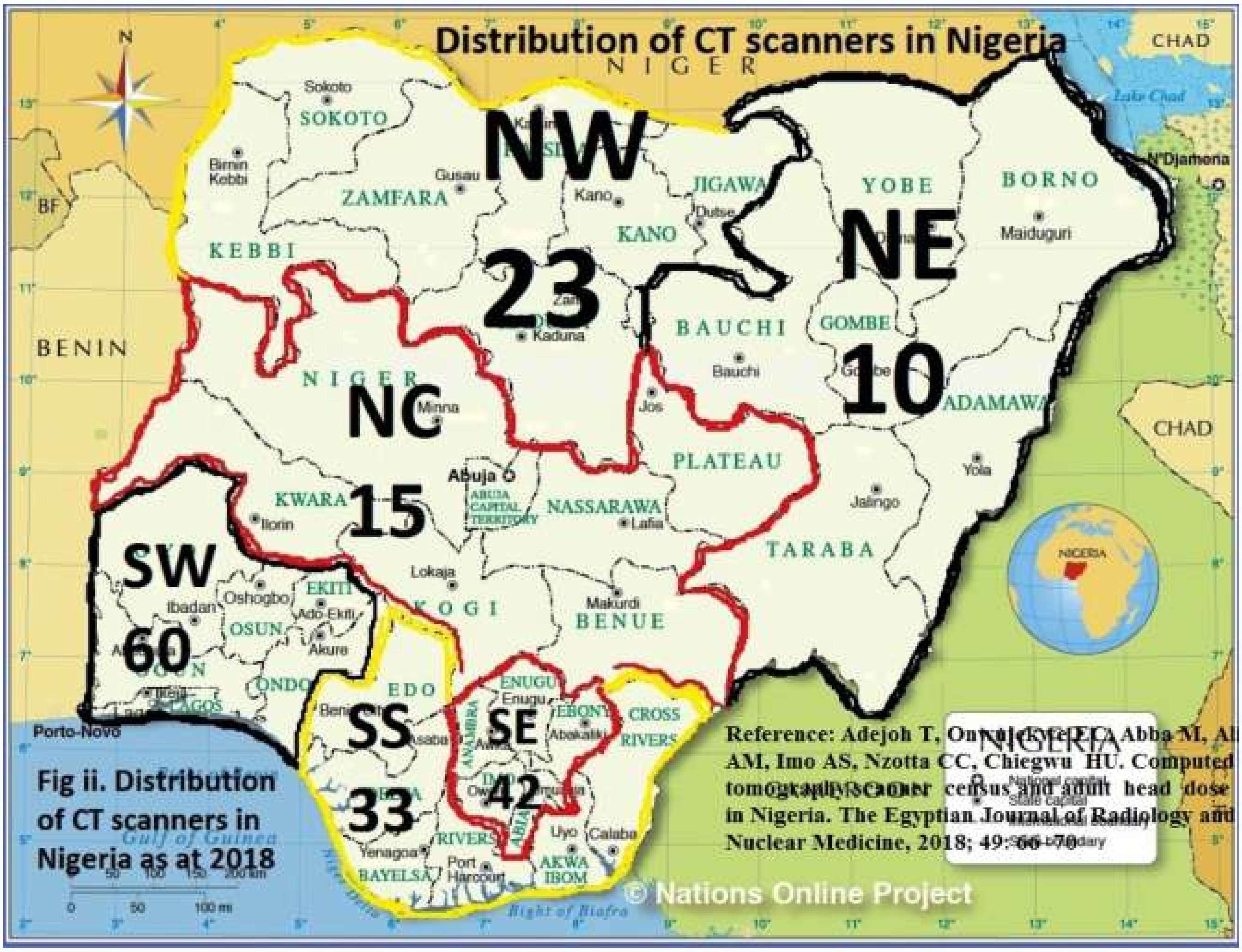


Fig ii. Distribution of CT scanners in Nigeria as at 2018

Recommendations

1. There is need for an urgent review of CT curriculum in Nigeria to embrace both image acquisition and dose optimization, rather than a curriculum standing solely on the former.
2. The RRBN is urged to establish, or adopt and implement DRLs for CT and other modalities emitting ionizing radiation as part of quality control of practice of radiographers.
3. As part of acceptance testing for newly installed CT scanners, effectiveness of preset protocols should be investigated.
4. Radiation stakeholders in Nigeria (regulatory agencies, professional associations, and training institutions) are urged to align with the global mood and imperative of dose monitoring, reporting and control.

CONCLUSION

Radiographers in Nigeria and RRBN have moral and ethical obligation to mitigate ionizing radiation dose, especially that of CT. A quality control tool for dose-wise practice is the use of diagnostic reference levels (DRLs). Nigeria has a rich pool of independent publications that that could form the springboard for any action plan on DRLs locally and in the West African subregion. Finally, quality control of practice of radiographers should be considered flawed if implementation of DRLs is missing in their clinical space.

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