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Assessment of diagnostic reference levels awareness and knowledge amongst CT radiographers

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Abstract

Background: Reports indicated that numerous factors, including inadequate personnel knowledge, contributes to insufficient patient data for setting up diagnostic reference levels (DRLs) in developing countries. This study aims to evaluate the knowledge of DRLs as an optimisation tool amongst computed tomography (CT) radiographers in northern Nigeria. This is a quantitative cross-sectional study. A structured questionnaire was devised and distributed on site to sixty-two CT radiographers in northern Nigeria. A total of fifteen questions were included in the questionnaire focusing on DRLs, dose optimisation and dose descriptors generating quantitative data concerning overall CT radiographers' perceived knowledge and awareness about DRLs.

Results: A response rate of 77.4% (48/62) was achieved. About 83.3% of the participants declare DRLs awareness, and 37.5% carried out a local dose survey. The percentage correctly perceived knowledge of concepts; DRLs was 45.8%, dose optimisation (42%) and CT dose descriptor (39%). Radiographers with work experience ranging from 4-10 years had the highest score.

Conclusion: In this survey, deficiencies were noted in radiographers' knowledge about DRLs with precise knowledge gap in the implementation of local dose survey for DRLs and optimisation. There is a need for continuous radiographers' training with greater emphasis on dose optimisation and institutional based dose evaluation.

Keywords: Diagnostic reference levels, Computed tomography, Radiographer education, Dose optimisation

Background

The ongoing technological advancement and improved diagnostic capabilities of ionising radiation-based imaging modalities have led to expanding utilisation. Literature shows that there has been rapid increase in total annual requests for multi-detector computed tomography (MDCT) imaging over the last few years, globally [1]. Thus, computed tomography (CT) examinations represent about half of the total radiation load for diagnostic purposes at the moment [1, 2]. This increase in demand for CT examination is of serious concern to the scientific community, particularly due to potential risks of ionising radiation. The use of ionising radiation on patients is attributed to radiation-induced malignancies and death [2, 3]. Besides, a 2019 epidemiological study in line with findings reported in two other pieces of literature substantiates statistical significant increase risk of malignancy amongst children and adolescent patients undergoing CT examinations [3–5]. An increase in radiation-induced deoxyribonucleic acid (DNA) injury was also documented [6]. In this setting, full attention to radiation protection issues and appropriate information on the knowledge of diagnostic reference levels (DRLs) as an optimisation tool need to be assessed to ensure

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current CT imaging practice holds fast to the new criteria in radiation protection of patients and the ALARA (as low as reasonably achievable) principle [7, 8].

DRLs are investigational levels used to identify abnormal radiation doses (unusually high or low) for standard diagnostic medical X-ray imaging procedures as well as indicators of typical radiological practice in a centre, region or country [9]. DRLs are optimisation tools, and if the median value derived from a survey of doses are above the DRLs for the examination, then the facility should review its imaging protocol and determine if acceptable image quality can be achieved at lower doses [9–11]. Dose optimisation aims to establish a balance between image quality and patient dose in X-ray imaging, in addition to available support from the medical physicist and radiologist, this also requires the knowledge and skill of the radiographer to know what action will reduce the dose levels.

Periodic review of doses (DRLs) led to a substantial decline in dose levels as documented in national CT dose studies [9, 12]. However, lack of sufficient patient dose data for setting up DRLs is related to lack of qualified personnel, tools, appropriate methodology and coordination at the national level. These are the main factors limiting the setting up of DRLs in low and middle-income countries and the reason why practices in such countries are referenced to other countries' DRLs [8, 13]. Consequently, radiological practices in Nigeria are referenced to the United Kingdom (UK) DRLs values since there is no national DRLs at present [14–17]. These findings are of clinical concern because monitoring patient dose is a crucial prerequisite towards dose optimisation [13]. However, increased training and awareness on the relevance of dose monitoring amongst CT radiographers in the affected countries, including Nigeria, may increase the practice of local dose evaluation for identification and review or correction of abnormal doses.

General knowledge about CT, radiation protection and dose optimisation ought to be provided to radiographers beginning from their undergraduate education with further updates through continuous professional development (CPD) whilst in clinical practice [11]. Nigerian radiographers' training is an undergraduate course that leads to a bachelor degree in medical radiography. In addition, they are mandated to undergo a compulsory 2-week postgraduate CT course, yet the literature indicates deficiencies in radiation protection and quality assurance practices [17–20]; this finding thus obliges an evaluation of the knowledge of DRLs in dose optimisation amongst this personnel.

More so, request for CT imaging has increased in Nigeria, the most common is the brain CT followed by abdomen and chest CT respectively [14, 15]. Thus, radiographers must become aware of what might lead to high radiation doses and techniques for optimisation. Without this knowledge, the DRLs itself has only limited value. Besides, the relevance of increasing patient safety through dose monitoring (survey), dose-comparison and optimisation of radiological practices has been repeatedly emphasised [8, 21, 22]. Lately, emphasis on the need for developing countries to become more aware and develop DRLs for radiological practices is advocated [22]. More so, patient safety in CT practice cannot be overstated because of the increasing annual percentage contribution of CT imaging to global medical yearly radiation as a result of its growing demand [1, 4].

Hence, this study aims to assess CT radiographers' degree of perceived knowledge of DRLs as an optimisation tool in CT practice to provoke consideration of specific actions to increase knowledge and awareness amongst radiographers.

Methods

Study design

The study chose a cross-sectional design for the evaluation of radiographers' awareness and knowledge of DRLs as an optimisation tool in CT practice. Institutional ethics approval for this study was waived, as it did not include any risk groups. The participation was voluntary, and the participants' identity was anonymous.

Participants

Recruitment involved purposive sampling, and subjects were contacted by word of mouth or electronic mail in advance. The sampled radiographers had a minimum of a postgraduate certificate in computed tomography from the Nigerian institute of radiography in addition to a bachelor of medical radiography degree. To be eligible for the study, the participant needed to be certified medical radiographers practising in a centre (private or public) where a CT scanner was available. It is relevant to elucidate that a large proportion of radiographers work in centres which do not have a CT scanner, such radiographers were excluded in this study. According to a national report on radiology published in 2015, 50 units of CT scanners were available in the country [23]. However, to the best of the researchers' knowledge, the exact estimate of CT radiographer's population in the country is not available in the literature.

Settings

The study was conducted between June and November 2019, and participants were drawn covering the northern region of Nigeria only, due to the large geographical size of the region and closeness to the researchers. The questionnaire was first piloted with four radiographers in the primary author's institution, and this resulted in a few

Table 1 Participants' average knowledge score according to years of experience

Participants' experience	Number (*N*)	Average score	Standard deviation
< 3yrs	19	4.0	1.7
4-10yrs	17	4.1	1.8
>10yrs	12	3.2	0.8
Total	48	3.8	1.6

formatting changes and rephrasing of some questions to improve the clarity.

Questionnaire

A self-administered questionnaire modified from Paoliccchi et al. [24] and incorporated with additional questions that addressed the aims being considered in this study was delivered to participants on site by the researchers. After a second reminder, fourteen participants did not return the questionnaire. The questionnaire was designed to assess the perceived knowledge of DRLs as an optimisation tool in CT practice and radiation protection amongst radiographers who scan patients for CT examinations. It consisted of 15 questions, divided into three sections in a multiple-choice, true/false and open-ended format. The first section contained basic questions to establish demographics, whilst the second section focused on issues to determine awareness about essential general radiation protection and optimisation in CT. The third section focused on knowledge and awareness about DRLs and its application as an optimisation tool. Correct answers to the questions on knowledge of DRLs (n = 8) were given a score of 1, whilst incorrect answers were given a score of 0. Each person's knowledge score was determined by the sum of the individual's total score minus the overall available score.

Table 2 Typical local CT DRL values (75th percentile) for common CT examinations in the study population

Study	Head	Chest	Abdomen/pelvic
	$CTDI_{vol}$/DLP	$CTDI_{vol}$/DLP	$CTDI_{vol}$/DLP
Adult			
Adejoh et al. [16]	63/1431		
Ekpo et al. [25]	61/1310	17/735	20/1486
Zira et al. [26]	67.9/-	18.83/-	19.20/-
Abdulkadir et al. [14]	60/1024	10/407	15/757
Children			
Ekpo et al. [27]			
Newborn	27/1040		
1yr	37/988		
5yr	48/1493		
≥10yrs	54/1824		

Note: Volume weighted computed tomography dose index ($CTDI_{vol}$ in mGy) and dose length product (DLP in mGycm)

Statistical analysis

Data analysis was performed using the SPSS software version 20 (SPSS Inc., Chicago, IL). Descriptive analysis (frequency and percentage) was used to analyse the response from the participants. Categorical data were presented in mean and standard deviations. The reliability of the questionnaire was assessed for internal consistency with a Cronbach's alpha (α) coefficient at a 95% confidence interval with the threshold for statistical significance set at $P < 0.05$. The test was performed to measure the extent to which the questions in the survey measure the knowledge of DRLs.

Results

In total, 62 questionnaires were distributed to radiographers with 48 (77.4%) being returned. The survey had acceptable internal reliability of $\alpha = 0.7075$, after questions were subjected to the Cronbach's alpha (α) test. Female radiographers comprise 12.5% (6 of 48) of the total number of participants. Participants and centres scan an average of 4.2±1.25 patients daily. General Electric (GE) CT brand account for 90% whilst Siemens Electronic constitute the remaining 10% percent of the scanner brands in the sampled study population. The CT scanner slice count (number of rows of detectors) range from 4 to 16 slice scanners. Radiographers with work experience (4–10 years) had the highest average knowledge score compared to radiographers in other categories of years of experience, as shown in Table 1. Radiographers with work experience (10 years and above) obtained the least average knowledge score.

Typical local CT DRL values (75th percentile) for common CT examinations in the study population for both adult and children as reported in literature are presented in Table 2. Most of the studies assessed dose in adult CT, whilst only one study assessed and reported dose values in children CT.

Awareness about general radiation protection and dose optimisation

The majority of participants (83.3%) declare awareness of dose display on the console of their CT machines. Participants were asked which of four dosimetry

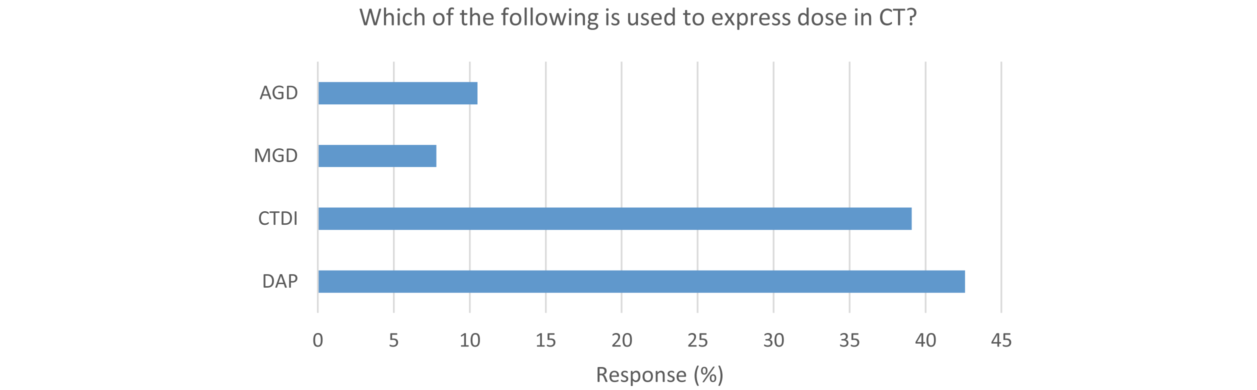

Fig. 1 Participants' knowledge of dose descriptors

acronym options (DAP, CTDI, MGD, AGD) expresses dose in CT, about 39.5% of participants identified CTDI (computed tomography dose index) as the correct dose indicator for CT dose report (Fig. 1). When asked to describe the concept of dose optimisation, 43.7% of radiographers correctly explained and showed familiarity with the concept (Fig. 2). Furthermore, 52.0% of participants correctly stated that scan protocols were relevant in dose optimisation (Fig. 3). Study participants were asked if they selected distinct scan protocol for adults and children scans, conversely, participants were aware of separate protocols for both patient group. However, 12.5% of participants rarely forget to select the appropriate protocol, and 58.6% reveal they always choose the proper protocol when scanning both patient categories.

Basic knowledge and awareness about DRLs as an optimisation tool

When asked about DRLs, a vast majority of the respondents (81.2%) declare awareness about the term DRLs and 47.9% of participants correctly identified the correct definition of the concept of DRLs (Fig. 4). However, 52% of participants were not aware of the exact function of DRLs (Fig. 5). Nonetheless, when asked if they undertook dose survey and compared dose from their facility with DRLs, 37.5% confirmed to have done a dose survey (Fig. 6). Majority of respondent stated not to have participated in the evaluation of scan protocols due to perceived abnormal dose report when asked if they have considered a review of scan protocol due to unusual dose report after a dose survey and evaluation.

Discussion

Perhaps due to curriculum upgrade, younger radiographers were told about DRLs during training, which the older radiographers may not have been adequately informed. Participants' years of work experience did not impact their knowledge scores; the need for continuous on-the-job training to improve radiographer's knowledge is evident. Moreover, available pieces of literature reported mixed findings with regards to years of work experience ranging from positive influence [28] and no influence [24, 29] on radiographer's knowledge. Nevertheless, the result stresses the necessity and importance of on-the-job re-training and education to improve the radiographer's skills and expertise.

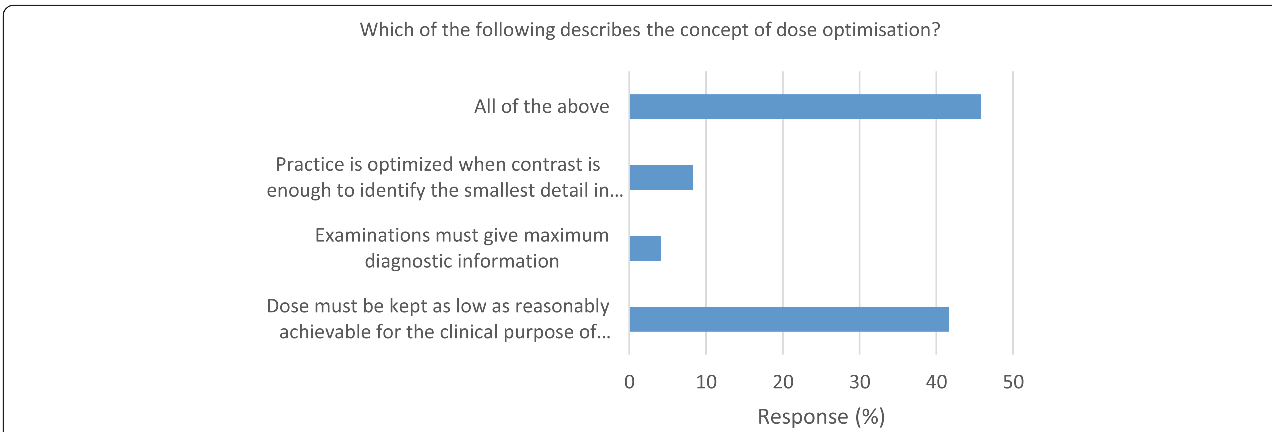

Fig. 2 Participants' knowledge of dose optimisation

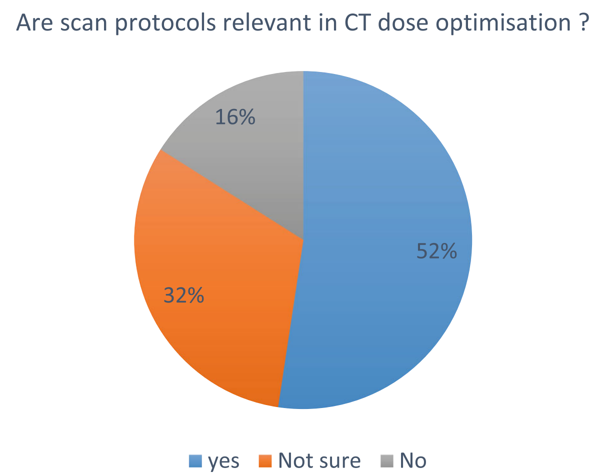

Fig. 3 Participants' knowledge of scan protocols

Awareness about general radiation protection and dose optimisation

Previous studies attributed weak radiation protection culture, which probably emanated from insufficient knowledge and familiarisation during training with the reported inadequate radiation protection knowledge and practices amongst radiographers [30–33]. Interestingly, it is of concern that a low percentage of participants in this study were able to identify CT dose descriptors as well as the correct description of dose optimisation. Thus, it might undermine achievement of potential dose optimisation. However, it is established that on-the-job continuous medical education (CME) in radiation protection was effective and substantially improved radiographers' performance, radiation protection knowledge and skills [29, 34–36].

On the other hand, slightly above 50% of the participants were aware that scan protocols are relevant for dose optimisation. Nevertheless, more awareness is required because scan protocols available to radiographers were mostly as set up by the vendor application specialists and then might not be adjusted again if images appear satisfactory for diagnosis. Furthermore, unlike conventional X-ray imaging, the wide latitude of the CT modality and advanced inherent image processing capabilities makes the adverse effect of overexposure barely discern the image quality [28, 29]. Hence, there is a need to periodically monitor, evaluate and compare local doses with DRLs to detect potential abnormal doses (under and overexposure) that may necessitate a review of protocols and optimisation [9]. Equally, a proper understanding of the optimisation principle facilitates skills and knowledge of dose reduction and the protection of patients [24], and the lack of understanding this principle limits the potential of achieving optimised CT practice.

Knowledge and awareness about DRLs as an optimisation tool

The evaluation of radiation doses and comparison of local practice with DRLs becomes critical, especially in the light of reported overexposure or higher dose values following comparison of some local (Nigerian) CT practices with international DRLs [14–16]. Diagnostic reference levels can assist in reducing patient dose from CT examinations, once scanning protocol change or improved after a review [37]. Consequently, DRLs proved over the years as a useful tool in achieving optimisation of CT practice and should be repeated periodically [17, 21, 22]. More so, radiographers' knowledge and skills about dose reduction strategies as well as the cooperation from medical physicist and radiologist are equally essential.

Almost two-thirds of participants did not undertake local dose survey for comparison with DRLs. However,

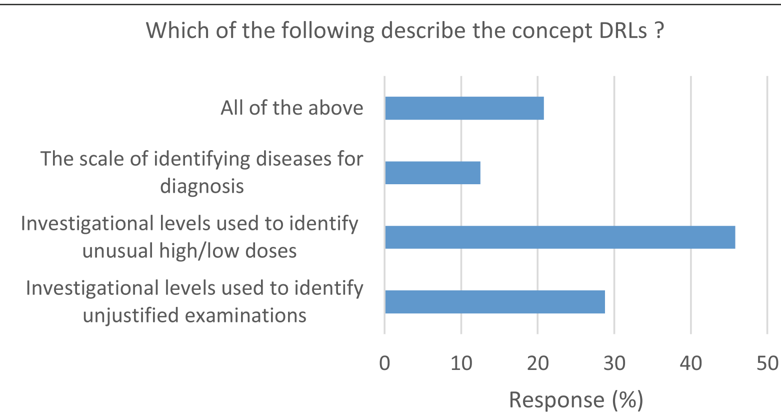

Fig. 4 Participants' knowledge of the concept DRLs

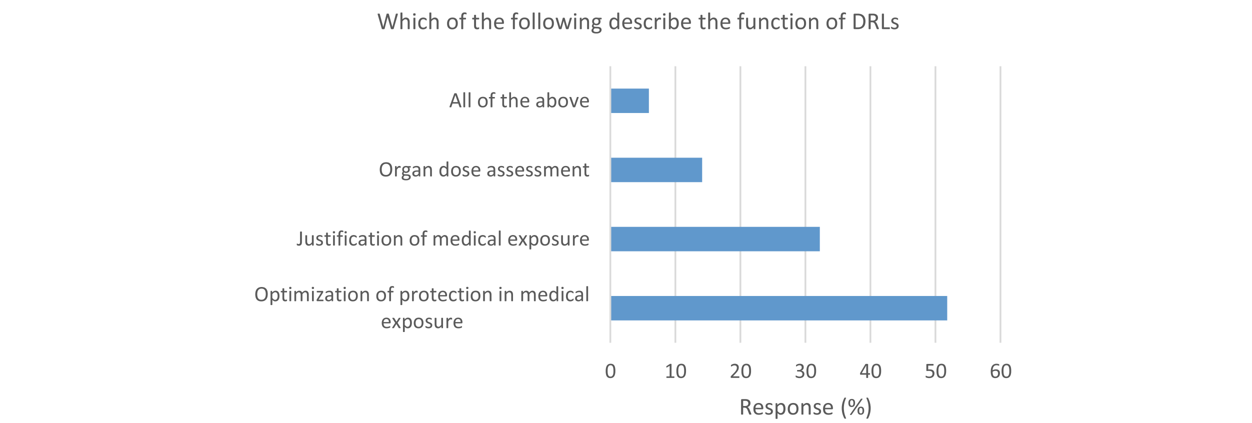

Fig. 5 Participants' knowledge of the function of DRLs

majority of the participants indicated awareness of the term DRLs. As shown by the results, the majority of participants were not carrying out dose monitoring (Fig. 6). Radiographers in this study show limited awareness of the relevance and the relationship between dose optimisation and dose survey for dose comparison. The observed limited consciousness may partly be explained by the lack of national DRLs, which may have contributed to the low level of perceived knowledge and non-performance of dose surveys as equally opined by Mahmoudi et al. [29]. However, where there is no national DRLs, it is valid and recommended to compare local dose values with relevant international DRLs [8]. The observed low number of dose survey might also be attributed to the lack of clinical diagnostic medical physicist personnel in majority of the radiological centres [38, 39]. In similar studies, radiographers' report shows a similar trend in other countries, where a more substantial proportion (86% and 96.5%) of respondent

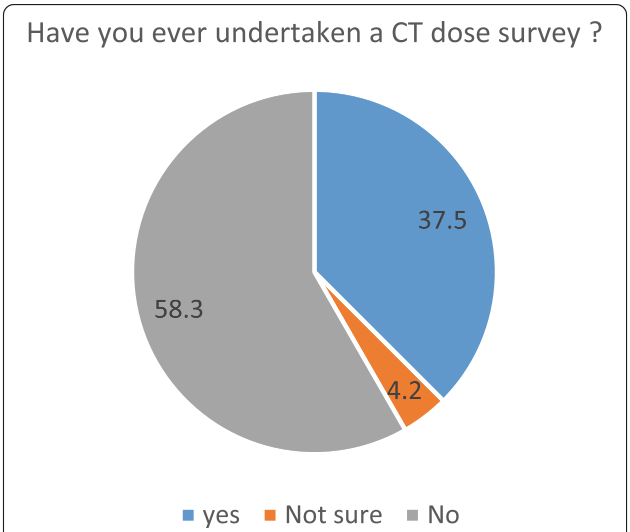

Fig. 6 Description of participants' who undertook a CT dose survey

radiographers show general awareness of DRLs and high mean score value (8.55) but listed wrong reference dose values, and thus, scored low (mean; 1.78) when specific questions were asked about DRLs [28, 29, 40]. Similarly, a large proportion (86%) of radiologists were unaware of the American College of Radiology (ACR) DRLs for three types of examinations [28]. The results underscore the need to provide radiographers with adequate knowledge and skills on dose optimisation as part of actions to improve patient protection and reduce risk.

Staff training, together with the evaluation of local dose values and comparison with DRLs, were previously shown to be efficient in optimising dose in CT practice [41]. Moreover, CT hardware and software technology continues to advance steadily with the introduction of newer dose optimisation techniques [12]; hence, radiographers' knowledge needs to be updated frequently to be efficient in the discharge of their duties.

The authors recommend the following measures that may improve the current practice; enhanced training and re-training (CPD/CME) of undergraduate and practising radiographers on dose optimisation, application training by CT vendors and periodic local (centre) dose evaluation as well as coordination of viable regional dose monitoring for the establishment of a national DRL.

The limitations of this survey are based on the fact that though the response rate was reasonable, we recognise that the responses reported may not necessarily be a representative of the entire population of CT radiographers in northern Nigeria. The study could not cover other parts of Nigeria due to the remoteness and overwhelming geographical size of the country, which may be overpowering for the researchers. Furthermore, our study did not ask for specific examination DRLs values as the study did not target any particular examination type or patient category but the general overview of the respondent's awareness about DRLs. We also recognise that as part of the limitations of the questionnaire survey, some participants might not be truthful in responses concerning their actual practice and knowledge.

Conclusion

This study strives for better CT practice through an emphasis on DRLs amongst radiographers in northern Nigeria. There is an urgent need for implementation of training in CT dose optimisation and the need for radiographers to take actions that will improve their knowledge. The main priorities are on the implementation of local dose survey for DRLs and optimisation. Majority of radiographers in this region have limited awareness of DRLs as an optimisation tool as well as the need for periodic dose evaluation. Continuous on the job training will considerably influence radiographers' knowledge of CT dose optimisation and thereby reduce patient dose in line with the ALARA principle of radiation protection.

Abbreviations

DRLs: Diagnostic reference levels; CT: Computed tomography; ALARA: As low as reasonably achievable; CME: Continuous medical education; CPD: Continuous professional development; CTDI: Computed tomography dose index; $CTDI_{vol}$: Volume weighted computed tomography dose index; DNA: Deoxyribonucleic acid; DAP: Dose area product; DLP: Dose length product; MDCT: Multidetector computed tomography; MGD: Mean glandular dose; AGD: Average glandular dose; GE: General electrics; ACR: American College of Radiology

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Authors' contributions

MKA did the conception of the study. All authors participated in the study design, questionnaire draft and data collection. First drafting was done by MKA and revised by AA and ADP. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this published article.

Ethics approval and consent to participate

(Not applicable) Institutional ethics approval for this study was waived as it did not include any risk groups, participation was voluntary and the participants' identity was anonymous.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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