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Examining the Decision of Radiographers in the Selection of Computed Tomography Scan Radiation Doses

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Abstract: Medical radiation is a controllable source and should be applied on individualized basis to determine whether each patient fits the appropriate criteria for the diagnostic procedure. Appropriate justification of requested CT examinations should ensure that benefits outweigh the risk. CT scan protocols and radiation doses vary greatly across countries and are primarily attributable to local choices regarding technical parameters, rather than the patient, institution, or machine characteristics. These variations call for optimization of doses to consistent standards. This was a mixed methods study, with quantitative and qualitative approaches, undertaken in Uganda. This study involved radiographers scoring the effects of various CT best-practices on dose selection using a Likert scale. The qualitative component explored factors influencing CT scan technical parameter selection, the barriers, and facilitators to best practices to CT radiation protection. The male to female ratio was 3.5: 1 and the average age was 30 years with a range of 21 – 40 years. The respondents either agreed or strongly agreed that Diagnostic Reference Levels were important in dose selection. Key factors influencing the selection of CT scan doses included CT scan machine, examination time, age and body size. Key barriers to best practices were the type or level of health facility, radiographer, and government level related and the facilitators to best practices also included type or level health facility, radiographer and regulator related. Based on the findings, Diagnostic Reference Levels (DRLs), the make, model and year of manufacture of the CT equipment were important in dose selection. Radiographers had limited training on DRLs, and majority were concerned about the lack of these DRLs. Regular training will be designed and implemented for the radiographers through the professional bodies and the regulator to educate the radiographers about CT radiation scan dose selection to optimize patient radiation dose and image quality.

Keywords: Radiographers, Decision Making, Selection, CT Scan Doses, Uganda

1. Introduction

The World Health Organization (WHO) defines ionizing radiation as a type of energy released by atoms in form of electromagnetic waves [1]. The spontaneous disintegration of atoms is called radioactivity, and the excess energy emitted is a form of ionizing radiation. Radiation damage to tissue and/or organs depends on the dose of radiation received, or the absorbed dose which is expressed in a unit called the gray (Gy) [1]. During any radiological examination, the potential damage from an absorbed dose depends on the type of radiation and the sensitivity of the different tissues and organs. Before the radiographer applies ionizing radiation to the patient, the acceptable and ethical practice of radiography should involve reviewing the risk-benefit profile associated with the requested examinations [2].

There are increasing opportunities to improve patient care with computed tomography (CT), however, this also comes with challenges. Since the use of radiation is always premised on the balance between benefits and risks, it is important to understand the patterns of use and increasing application of CT [3]. Medical radiation is a controllable source and should be applied on individualized basis to determine if each patient fits the appropriate criteria for the diagnostic procedure [4]. The final point of this control is usually the radiographer performing the CT scan examinations.

CT scan protocols and radiation doses vary greatly across countries and are primarily attributable to local choices regarding technical parameters, rather than the patient, institution, or machine characteristics. These variations call for optimization of doses to consistent standards [5].

A survey of CT scan doses in 2010 at seven public hospitals in the Republic of Belarus reported considerable variations in the CT dose indices (CTDI) [6]. In this study, it was evident that the protocols needed to be optimized for some of the CT scanners.

A study by Sigal et al (2014) also identified the increase in CT radiation exposure in recent years and the need to utilize different approaches for dose standardization and optimization [7]. A similar study in Korea in 2010, identified that significant protocol adjustments were often needed to reduce patient exposure to international standards [8].

When analyzing medical images, several factors must be considered including patient protection and safety, image quality, and clinical outcomes [9]. Although ionizing radiation has for long been recognized as a potential carcinogen capable of harming patients, the long-term derived benefits have always been acceptable because of the diagnostic and therapeutic benefits derived from its use [10].

There are a vast number of combinations of CT scan parameters for users to choose from which produce varying blends of image quality and dose, some of which may be manufacturer specific. However, default settings and manufacturer recommended protocols could be designed to optimize image quality rather than the patient dose [11].

Justification in radiography often forms part of the duty to patient care in clinical practice and as such requires the evaluation and clarification of requested examinations [12]. Radiographers can, therefore, prevent unnecessary radiation exposure through the justification of medical exposures by ensuring the clinical benefits offset the radiation detriment [13, 14].

Foley et al. (2021) reported that to ensure image quality optimization, users must tailor CT scan parameters to match the indication, the region of the body being scanned and patient size since not all examinations require the highest level of detail [15]. This, however, requires a specialized understanding of the CT scanner along with a time input which is usually not insignificant within busy departments. Large variations were noted in the dose between sites and across countries, even for similar-sized patients [15].

Ideally, the radiographers who are the apparent gatekeepers between the patient and unjustified ionizing radiation should be capable of informing the radiologist or referring physician if the referrals are deemed unjustified. Since justification is a fundamental principle of radiation protection, radiographers who actively participate in the decision-making process would ultimately contribute towards improved patient care and management [16]. In the context of developing countries where the use of CT has increased exponentially as a diagnostic procedure, there is a dearth of published literature documenting factors that influence radiographers' decisions when selecting CT scan radiation doses. The purpose of this study therefore was to examine the decision of radiographers in the selection of radiation doses during CT scan examinations.

2. Methods

2.1. Study Design

A concurrent mixed method design was used in which both quantitative and qualitative methods were employed [17]. The use of the mixed methods was aimed to improve the rigor of the study as well as the validity of the findings. In addition to the quantitative component, there was need to acquire an in-depth understanding of the factors influencing the selection of CT doses, barriers and facilitators to best practices to CT radiation protection amongst radiographers through qualitative techniques.

2.2. Study Population

The study involved radiographers who routinely performed CT scan examinations in the selected radiology departments.

2.3. Sample Size Estimation

The sample size was sixteen [18] CT scan radiographers varied by type of health facility namely, private versus public, sex, the cadre of radiographer and location of health facility (i.e. rural versus urban). In absolute terms, we planned to include two radiographers who worked in a private health facility, two radiographers that worked in a public health facility, two male radiographers, two female radiographers, two radiographers, two senior radiographers, two radiographers who worked in a rural area, two radiographers who worked in an urban area following the procedure described by Guest et al [19]. However, we interviewed a total of eighteen (18) radiographers since this was the point where data saturation was achieved.

2.4. Sampling Method

Purposive sampling was used with special interest in information-rich participants. Mugenda and Mugenda, 1999 observed that purposive sampling is a sampling technique that allows a researcher to use cases that have the required information for the objectives of the study [20]. Therefore, we handpicked the participants who had information needed to address the research aim.

2.5. Data Collection Procedures

Qualitative data was collected using key informant interviews (KIIs) following appointments with the selected participants. We used a pre-tested interview guide to assess the characteristics of radiographers, the factors that they considered in the selection of CT doses, their views regarding the facilitators and barriers towards best practices in CT radiation protection, as well as their suggestions on how the best practices in CT radiation protection can be achieved. Interviews were conducted in English and responses from the participants were audio-recorded. Because of the open nature of unstructured interviews, probing was commonly used to obtain deeper information. Quantitative data was also collected using structured questionnaires and data focused on the socio-demographic characteristics, opinions about factors affecting the best practices to CT radiation protection among radiographers in Uganda.

2.6. Data Management and Quality Control

For the qualitative data, the recorded interviews were transcribed in verbatim. At the end of each interview, there was a recap of the researcher's interpretation to the participants for verifications. The transcripts were reviewed several times to ensure that the contents were well captured, this audit trail also served as a technique to ensure the credibility of the data. The transcribed interviews were exported to OpenCode version 4.02, a Computer-Aided Data Analysis Software (CAQDAS) for coding and analysis. Two independent research assistants with experience in conducting qualitative research and the PI conducted the analysis. They read the scripts separately and met thereafter to discuss areas of agreement or disagreements.

The moderator and note-takers were well versed with medical research. They were trained by the principal investigator in all aspects of data acquisition. The interviews were conducted at the health facility in a private space which ensured that participants felt comfortable to discuss the issues that were under investigation. Analysis of results was carried out independently by the PI and research assistants, which also ensured the accuracy of reported findings. Raw data was used to obtain codes which were related to each other to form sub-themes and themes.

2.7. Availability of Data

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

2.8. Ethical Considerations

The study was approved by the Makerere University School of Medicine Research and Ethics Committee (Protocol No REC REF 2015-150). Informed consent was obtained from each participant prior to collecting data and they were assured of the confidentiality of the data provided.

2.9. Data Analysis

Quantitative data about the factors affecting best practices in CT radiation protection among radiographers in Uganda were assessed based on a 5-point Likert scale [21] where the possible answers ranged from; Always (= 5), Often (= 4), Sometimes (= 3), Rarely (= 2) and Never (1) responses or Strongly agree (= 5), Agree (= 4), Neutral (neither agree nor disagree) (=3), Disagree (= 2), and Strongly disagree (= 1). We summed up item responses to create a score (summative opinion index) for a group of items [21].

For qualitative data, thematic inductive analysis was used. The analysis was conducted with the help of OpenCode version 4.02 software. This involved reading the raw data to generate codes. The codes were related to each other to generate common patterns that gave rise to sub-themes and themes.

3. Results

3.1. Quantitative Findings

The socio-demographic characteristics of the respondents are presented in Table 1.

Table 1. *Social demographics characteristics of the respondents (N=18).*

Variables	Frequency	Percentage %
Age (years)		
21 – 30	08	53.3
31 – 40	07	46.7
Sex		
Male	14	77.8
Female	04	22.2
Cadre type		
Senior radiographer	03	17.6
Radiographers	14	82.4
Cadre's years of professional experience		
1 – 5	09	50.0
6 – 10	04	22.2
More than 10	05	22.8
Health facility type		
Government	04	22.2
Private	14	77.8
Health facility location		
Greater Kampala Metropolitan Area	13	72.2
Upcountry	05	27.8

Eighteen radiographers responded to the questionnaires, three respondents did not indicate the age and one did not indicate the carder type; most of the respondents were male (77.8%) and fifty-three per cent were of the age group 21-30 years. Most of the radiographers (50%) had practiced for between 1 - 5 years, the majority (77.8%) were in the private facility and 72.2% of the respondents were working in the greater Kampala area.

The factors affecting best practices to CT radiation protection among radiographers in Uganda are presented in Table 2. Fifty and forty-four percent of the respondents strongly agreed or agreed that DRLs were important in the patient dose selection with a summative opinion index of 45 and 32 respectively. None of the respondents either disagreed or strongly disagreed.

Table 2. *Factors affecting best practices to CT radiation protection among radiographers in Uganda (N=18).*

Variable (Likert scale item)	**N, (%) response**	**Summative opinion index**
Do you agree that DRLs is important to patient dose selection?		
Strongly agree	9 (50.0)	45
Agree	8 (44.4)	32
Neutral (neither agree nor disagree)	1 (5.6)	3
Disagree	0 (0.0)	0
Strongly disagree	0 (0.0)	0
How often do you get trained in DRLs issues?		
Always	0 (0.0)	0
Often	3 (16.7)	12
Sometimes	4 (22.2)	12
Rarely	7 (38.9)	14
Never	4 (22.2)	4
Does the model of the machine affect the radiation doses?		
Always	3 (16.7)	15
Often	4 (22.2)	16
Sometimes	8 (44.4)	24
Rarely	1 (5.6)	2
Never	2 (11.1)	2
Does the make of the machine affect the radiation dose?		
Always	2 (11.1)	10
Often	2 (11.1)	8
Sometimes	7 (38.9)	21
Rarely	3 (16.7)	6
Never	4 (22.2)	4
Do you agree that the year of purchase of the CT scan machine affects the radiation dose?		
Strongly agree	3 (16.7)	15
Agree	9 (50.0)	36
Neutral (neither agree nor disagree)	2 (11.1)	6
Disagree	2 (11.1)	4
Strongly disagree	2 (11.1)	2
Do you agree that the experience of a radiographer affects radiation dose		
Strongly agree	9 (50.0)	45
Agree	8 (44.4)	32
Neutral (neither agree nor disagree)	1 (5.6)	3
Disagree	0 (0.0)	0
Strongly disagree	0 (0.0)	0
Do you agree that the knowledge of a radiographer is important in radiation dose selection?		
Strongly agree	10 (55.6)	50
Agree	8 (44.4)	32
Neutral (neither agree nor disagree)	0 (0.0)	0
Disagree	0 (0.0)	0
Strongly disagree	0 (0.0)	0
In your facility, how often is the review CT DRLs done?		
Always	0 (0.0)	0
Often	2 (11.1)	8
Sometimes	4 (22.2)	12
Rarely	6 (33.3)	12
Never	6 (33.3)	6
Do you agree that regular training on CT scan issues is important in CT radiation dose selection?		
Strongly agree	9 (50.0)	45
Agree	6 (33.3)	24
Neutral (neither agree nor disagree)	1 (5.6)	3
Disagree	2 (11.1)	4
Strongly disagree	0 (0.0)	0
Does it concern you that your country lacks standardized DRLs?		
Always	9 (50.0)	45
Often	3 (16.7)	12
Sometimes	4 (22.2)	12
Rarely	2 (11.1)	4
Never	0 (0.0)	0

Concerning training in DRLs, (38.9%) were rarely trained while 22% were sometimes or never trained respectively with a summative opinion index of 14, 12 and 4. None of the respondents always received training on DRLs.

Forty-four percent of the respondents reported that the model of the machine sometimes influenced the radiation dose with a summative opinion index of 24. 22.2% and 16.7% reported that the model often or always affects the radiation dose, however, 11.1% reported that this never had an effect with summative opinion index of 16, 15 and 2. Similarly, 38.9% of the respondents reported that the make of the machine sometimes affects the radiation dose, this is followed by never and often or rarely at 22.2% and 16.7% respectively with a summative opinion index of 21, 4 and 6.

About 55.6% and 44.4% of the radiographers respectively strongly agreed and agreed that knowledge of the radiographer is important in the radiation dose selection. No respondent was neutral, disagreed or strongly disagreed with the above assertion. 33.3% of the respondents either never or rarely reviewed the CT DRLs in their facilities. This corresponded to a summative opinion index of 6 and 12 respectively. 50% and 33.3% of the radiographers either strongly agreed or agreed that regular training on CT scan issues is important in CT radiation dose selection. The corresponded to a summative opinion index of 45 and 24 respectively.

About 50%, 22.2% and 16.7% of the respondents were either always, sometimes or often concerned about the lack of DRLs in the country with a summative opinion index of 45, 12 and 12 respectively.

Most of the respondents had last CT DRL training either less than a year ago or between 1-2 years ago, then 27.8% and 16.7% of respondents last had their CT DRL training between 3-5 years and >5 years ago. 11.1% of respondents had never had CT DRL training.

3.2. Qualitative Findings

This study also set out to explore factors that influenced the selection of CT doses by the radiographers, facilitators to CT best practices and specifically barriers to best CT radiation practices. Analysis of data resulted into three major thematic areas namely: *Facilitators to best CT practices*; *hindrances to best CT scan practices* and; *barriers to CT radiation protection*:

Theme 1: Facilitators to best CT practices

The qualitative responses brought out the facilitators to best practices which were summarized into 3 sub-themes namely: health facility level facilitators, radiographer level facilitators and supervision related facilitators.

Healthy facility related facilitators: These were related to health facility level factors that encouraged best practices in CT radiation protection. They included availability of functional facilities, financial and administrative support from the health facility administration and health facility set-up.

"*There's a lead barrier and a lead door. Then they* [health care workers] *are given monitoring tools that are monitored every after 3 months. So every after 3 months they take the TLDs, they measure the dose*" (ID=02).

"A good relationship between the administration and the CT technicians, for example, if I discover a problem, like for instance if this machine needs calibration or maintenance, the administration has the money, they have to respond and get people to do the maintenance, they do the maintenance, they do the calibration." (ID=16)

Radiographer related facilitators: These included the knowledge and experience, vigilance in justifying examinations and patient education about radiation safety.

"*One is to verify that the patient you are going to work on is the right one, then the investigation asked for is the correct one, is it justifiable, is it really necessary, then patient preparation, after verifying this is the person, this is the correct investigation, because at times you have to communicate with the doctor to confirm to confirm if you feel this isn't really necessary."* (ID=12).

Supervision related facilitators: These facilitators were expressed about the level of the supervision by the atomic energy council, which is a supervisory body for the use of ionizing radiation in Uganda. They included prompt monitoring and supervision by the regulator as well as patient education.

"With the effort of the atomic energy council, it has greatly improved, because before we would not follow those specific instructions... The atomic energy council, it's a radiation board which makes sure that radiation- which makes sure that we follow the radiation rules, the radiation protection… We limit the radiation doses to patients, we make sure that the machines are in very good working conditions." (ID=09).

"..even monitoring because they do radiation monitoring periodically like every after 6 months they cannot spend a year without visiting this facility and any other facility. So, I think it has improved in the past 5 years because before that, we never used to have them come here, we were never forced to have radiation badges because right now you cannot do radiation without a badge." (ID=16).

Theme 2: Hindrances to best CT scan practices

This theme was about the hindrances to best practices for CT scans as reported by the radiographers. These included: health facility related hindrances and patient-related hindrances.

Health facility related hindrances: These referred to characteristics of health facilities that hindered the best practices for CT scan radiation protection. They key ones included: unavailability of protective gear, delayed repair of faulty equipment, heavy workload of the radiographers, lack of DRLs, model of machine, unnecessary bureaucracy, low payment of radiographers, inadequate knowledge of other health care workers and type of health facility. The following responses captured some of these insights:

"We don't have other gadgets which are required in form

of barriers when we are performing say CT scans one of them is a lead google, we don't have. We don't have lead skirts, we don't have a gonad shield." (ID=06)

"*Ah, we also had a unit the lead glass had some crack and there was leakage but for a given period of time and then it was later repaired but there were times when were delays in repairs of those radiation protective gadgets like the lead door, the lead glass*." (ID=04).

"Yes, how does that come in, you have many patients in the queue and even you have those ones doing well, so as you are trying to rush them.., you realise that sometimes you missed out either giving a lead jacket to one person or covering one person`s part and you are already around the examination, by the time you realize when it is late." (ID=18)

Patient related hindrances: The second sub-theme related to patient factors considered when selecting CT dose parameters. The emerging responses included patient age and size, the body part being scanned and the type of examination carried out. These can be contextualized by the following participant responses:

"I also look at the kV selection of course, if you are talking about the penetration, ah you would find like maybe the kids, maybe the infants, their bones are a bit soft, you do not need high penetration like high kV to penetrate, so you would just have to go down and still acquire a good image." (ID=13).

"……a small body, there is no need to give high mAs cause that one you end up giving a higher dose. If the subject is very big and you're giving a very low KV, that means three-quarters of the radiation gets, I would say absorbed into the body which is not the case for what we need. We don't need the radiation to be absorbed within the body, we need the radiation to go through the body… (ID=08).

Theme 3: Barriers to CT radiation protection

We also specifically explored barriers to best practices in CT radiation protection. From the responses, the major barriers to radiation protection during CT examinations were: health facility related barriers, patient barriers, radiographer barriers and government related barriers.

Health facility related barriers: These included characteristics of health facilities that hindered the best practices for CT scan radiation protection. These were unavailability of protective gear, delayed repair of faulty equipment, heavy workload of the radiographers, lack of DRLs, model of machine, unnecessary bureaucracy, low payment of radiographers, inadequate knowledge of other health care workers and type of health facility. The following responses illustrate some of these barriers:

"*Ah, we also had a unit the lead glass had some crack and there was leakage but for a given period of time and then it was later repaired but there were times when there were times when there were delays in repairs of those radiation protective gadgets like the lead door, the lead glass*." (ID=04).

"Ah, like, we don't have documented steps, of course there is experience, but also we have a CT manual which doses for different patients but those are many doses they tell you when you are doing this, you have to do this, but we rarely use it." (ID=16)

Patient related barriers: These included low levels of knowledge about CT radiation and uncooperative patients.

"*We receive different categories of patients, illiterate patients, literate and within the literate, there are those that are informed and those that are not informed. Very few people know these things. So you as a radiographer if the patient asks you, you should be in a position to answer…*" (ID=03)

"*At times there are patients who are uncooperative, expose the first time, the patient has moved, so you have to expose again. So that's all radiating the patient, although at times it is inevitable, cause you have to come up with the images*" (ID=02)

Radiographer related barriers: These barriers included radiographer characteristics such as radiographer inexperience, low level of knowledge and impatient radiographers as can be seen below:

"*Of course, that [concerns about CT radiation safety] happens where we have those who are learning, eh? then we have those who want to prove that they know, sometimes you find that somebody has exposed the patient but using the wrong protocol so has to exposes again, so that happens at times, eh."* (ID=02).

"There are some protocols which are quite slow but give low radiation doses and there are those protocols which are fast but, in the process, the patient gets high doses. So, there's always concern about that. And amongst us, people who are not a bit patient would go in for that fast protocol but at the end of the day, the patient gets a high dose." (ID=09).

Government related barriers: These factors were beyond the radiographers, health facility and patient or community-level barriers. They included barriers at the level of government bodies namely the atomic energy council such as poor supervision by this body as well as poor CT radiation protection in the rural areas. The responses below illustrated these barriers.

"*They* [Rural] *even have fewer radiation safety gears, we are not sure of the walls. Are they the recommended wall thickness? You will find units where you are just told to stand a distance (laughs sarcastically) but you are in the same room and you're exposed*." (ID=04)

4. Discussions

In this mixed-methods study, we set out to examine the decision of radiographers in the selection of CT scan radiation doses amongst CT scan technicians in Uganda. We interviewed eighteen radiographers in this study.

Most of the radiographers interviewed in this study were male, and young. There is no comprehensive demographic data in Uganda or within the region for the average age and sex of the radiographers, however the United States (US) and United Kingdom (UK) demographic data showed that there are more female radiology technologists at 56.6% and 74.6% respectively [21, 22]. This being a growing profession in

Uganda, the males have generally embraced the profession and the opportunities first, but there is an increasing number of females enrolling and graduating at as radiography professionals.

The opinions about the factors affecting the best practices to CT radiation protection among radiographers in Uganda was explored using a 5-point Likert score with a summative opinion index calculated. Most of the radiographers either strongly agreed or agreed that DRLs were important in-patient dose selection with a corresponding summative opinion index of 45 and 32 respectively. This was in tandem with studies by Järvinen et al (2017) on patient dose management and the use of diagnostic reference values for the optimization of protection in medical imaging [23]. They found out that training was rarely conducted for radiographers to highlight the need and importance of DRLs.

Twenty-two percent of the radiographers had never had any training on DRLs, it should also be noted that no radiographer always had training in DRLs by the time of this study. The low level of training and awareness is probably responsible for the low level of vigilance in the attempts to reduce and optimize CT scan radiation doses. Most of the radiographers either strongly agreed or agreed that regular training on CT scan parameters were important in CT scan radiation dose selection, no radiographer disagreed. In the paper by Järvinen et al, it was recognized and recommended that continuous training in radiation protection was importuning in radiation dose optimization [23], however, the Nigerian study by Abdulkadir et al found out that deficiencies in radiographers knowledge about DRLs with precise gaps in the implementation of local dose surveys for DRL and optimization [23].

Most of the radiographers reported that the model of the machine sometimes, often or always had an influence on the radiation doses. Most of the radiographers also reported that sometimes, never or rarely did the make of the machine influence the radiation doses dissipated to the patient. The year of purchase of the CT scan machine was also an important factor in the selection of the radiation dose, the recent machines had dose optimization parameters with dose reduction software. The radiographers either agreed or strongly agreed to this with a corresponding summative opinion index of 36 and 15 respectively. It is common teaching during the training of radiography that the make and model of the CT scanner directly influence the selection of the radiation dose to the patients and eventual dose optimization. The very old CT scan machines commonly available in the developing world also have old technology with no capabilities of altering the preset CT scan examination protocols with no inbuilt CT radiation dose reduction software.

The experience and knowledge of radiographers were one of the most important issues in the determination of CT radiation doses. Most of the radiographers in this study had either received CT DRL training in the past year or between 1-2 years ago. Interestingly some radiographers had never received any CT DRL training by the study time, this probably speaks to a fact that radiation protection and safety issues are not commonly addressed during the yearly scientific meetings or continuous professional developments. Half of the respondents were concerned about the absence of DRL standards for the country and no respondent was not concerned about the lack of National DRLs, the radiation safety of the patients could therefore improve if we developed national DRLs. In a Nigerian study by Abdulkadir et al, the majority of the radiographers had less than three years of experience in awareness and knowledge in CT radiation dose optimization, they therefore recommended continuous on the job training to considerably influence the radiographers' knowledge [23]. A Norwegian study by Kada et al among the radiographers to determine the knowledge on CT scan exposure reported that that the knowledge was satisfactory among the final year students of radiography, however the majority of the study participants 67% could not rightly state that kilovoltage peak (kVp) should be increased when patients have metallic implants, and milliampere seconds (mAs) should be increased as body part thickness increases (24). An Italian study by Paolicchi et al among Italian radiographers to assess the radiation protection awareness and knowledge found a substantial need for improved awareness on radiation protection issues [25]. These studies highlight the need to harmonize the knowledge among CT scan radiographers. There is a need for training for the radiography students while at school and the working radiographers to develop a crop of well-grounded and knowledgeable radiographers in the CT scan radiation practice with the eventual beneficiaries being the patients that come for CT scan examination.

The key informant interviews addressed the following areas namely, factors influencing the selection of CT scan doses, barriers to CT scan radiation protection and facilitators to best practices in CT radiation protection respectively.

We categorized the emerging themes that influenced the selection of CT scan doses into the machine, radiographer and patient factors with the sub-theme influencing the selection of CT scan doses were machine factors and the time of the examination. Some radiographers mentioned that the make of the machine was a factor that influenced the selection of CT doses. It was reported that some 'machine make' had pre-set protocols; this ensured that the protocols were adjusted to accommodate the average Ugandan patient. However, R Smith-Bindman et al in their study involving two million adult CT scan examinations in over seven countries found out that CT scan protocols vary greatly across countries and this is attributed to the local choices of technical parameters other than the machine characteristics [5]. There are also a vast amount of combinations of CT scan protocols to choose from, some of which may be manufacturer specific with dose reduction and iterative reconstructions like some of the newer machines we found in our study [11].

The patient factors that influenced the selection of CT scan doses were the body part being examined, age of the patient, size of the patient and type of the examination. All these were placed into consideration when selecting the radiation doses by the radiographers. The body part or area under scan influences the CT doses administered to the patient. Additionally, some scans combined different body parts with different thicknesses and as such the dose had to adjust to be adjusted accordingly to optimize the image acquisition. The CT scan parameters must be matched with the presenting indication, region being scanned and the patient size to optimize the imaging [15].

This however brings in a lot of subjectivity, perhaps this was why experience came in handy as a remedy in reducing and optimizing CT radiation doses. It will however be imperative to have quantitative parameters to influence and determine the CT scan radiation dose parameters based on the indication, age, sex and patient weight or body habitus [5, 6, 23, 24].

The barriers to the best practices were also explored and the emerging theme included health facility barriers, patient or community-level barriers, radiographer level barriers and Government level barriers. The barriers were unpacked into unavailability of protective devices, delayed repair of faulty equipment, heavy workload of the radiographer, lack of DRLs, the old model of the machines, unnecessary bureaucratic tendencies, low payment of radiographers, inadequate knowledge of other health care workers and type of health facility. Most radiographers regarded patients as having very low knowledge about CT radiation practices. The misconceptions reportedly ranged from not being bothered about CT radiation, to fear that the radiation from CT scans would kill them instantly. This low level of knowledge is attributed to a lack of proper patient information during the consent and a lack of sensitization programs for the public by the professional body or regulators.

The radiographer level barriers included radiographer characteristics such as radiographer inexperience, low level of knowledge and impatient radiographers. Some of the radiographers were fresh graduates from school with little practical knowledge or no previous exposure to sophisticated CT scan machines. This coupled with low level of knowledge was an enormous hindrance to optimizing CT scan radiation doses. The radiographers being the apparent gate-keepers between the patients and unjustified ionizing radiation, must be adequately equipped and trained to ensure that the workplace is safe for the patients and the radiographers at all times [15].

Government level facility barriers included poor supervision by the atomic energy council and poor CT radiation protection in the rural areas due to poor enforcement. It was also reported that the council also visited the facilities late after being called in where there were issues identified. The regulator being one of the key stakeholders in the safety of the patients, stakeholder engagements will be held to discuss these and explore other emerging issues.

The facilitators to best practices in CT scan radiation protection were explored under the following themes which included health facility level facilitators, radiographer level facilitators and regulator-based facilitators. The health facility facilitators of best practice were the presence of functional facilities, the presence of protective shields, support from administration and the general hospital set-up.

The radiographer level facilitators were radiographer knowledge and experience, patient preparation and scan justification and patient education. And finally, the radiographer-based facilities were effective monitoring and supervision and education by AEC. Justification of all radiological examinations often forms part of the duty to patient care, this always requires evaluation and clarification of request forms [12]. To ensure that the clinical benefits offset the detrimental radiation effects, the radiographers can only prevent unnecessary radiation exposure through the justification of requested radiological examinations [13, 14].

The key strength of our study was the mixed method nature of this study in understanding the decision of the radiographers in the selection of CT radiation doses. With this information, it will be possible to have targeted interventions to address the bottlenecks to optimizing CT scan radiation doses by radiographers in Uganda.

5. Implication to Practice

Regular training will be designed and implemented for the radiographers through the professional bodies and the regulator to educate the radiographers about CT radiation scan dose selection to optimize patient radiation dose and image quality. There is an urgent need to develop the Ugandan national indication based DRLs to guide radiation dosimetry and patient safety. There will also be a need for stakeholder engagements namely the patients, medical workers, hospital administrators and regulatory authority on the facilitators and the barriers to best practices.

6. Conclusions

Based on the opinion of the radiographers concerning CT scan radiation doses, DRLs, make, model and year of manufacture of the CT scanners were found to be important in-patient dose selection. The radiographers rarely had training on DRLs, and the majority were concerned about the lack of DRLs for Uganda.

The factors that influenced the selection of the CT scan radiation doses were the make of the machine, examination time and patient characteristics like age and weight. The barriers to the best practices in CT radiation protection were unavailability of protective devices, delayed repairs of faulty equipment, lack of DRLS, an older model of CT scan machine, administrative bureaucratic tendencies, low level of knowledge amongst the community and poor supervision by the regulatory authority. Facilitators to the best practices were functional facilities, administrative support, radiographer experience, knowledge and adequate supervision by AEC.

Conflict of Interests

The authors declare that they have no competing interests.

Data Availability Statement

All the data for this work is hereby embedded in the result section of this paper.

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