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INDICATION-BASED TYPICAL DIAGNOSTIC REFERENCE LEVEL FOR BARIUM SWALLOW EXAMINATION AT THREE CENTRES IN KAMPALA, UGANDA, A CROSS-SECTIONAL STUDY.

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ABSTRACT
Introduction
The reduction in utilization of barium examinations is attributable to excessive exposure to ionizing radiations but also due to more advanced imaging modalities. Diagnostic Reference Levels (DRLs) are employed in identifying unusually high radiation doses so that corrective action can be taken. DRLs are not established in many African countries, Uganda inclusive.

Objective
To determine the Typical Diagnostic Reference Level for barium swallow examination of patients with dysphagia at three centers in Kampala, Uganda.

Methodology
It was a cross-sectional, descriptive, and analytical study. It involved 90 adult patients with dysphagia, who were consecutively recruited and underwent barium swallow examination. The exposure parameters were recorded and used to calculate radiation doses, from which the 50th percentile was derived as the Typical diagnostic reference level.

Results
The overall mean; kilovoltage (69.4 kilovolts), Fluoroscopic time (2.5 minutes), and outcome dose area product (6.4 Gycm2) had significant differences between the 3 centers (p-value =0.001,0.001,0.006) respectively. The overall mean current was 27.1mAs, without significant differences between the 3 centers ($p = 0.0197$). There was a statistically significant ($p = 0.002$) positive relationship between radiation doses and BMI. There was a negative relationship between radiation doses and age. The median outcome dose area product was 5.7Gycm2which was the Indication based Typical DRL for the barium swallow examination.

Conclusion
There were significant differences in exposure factors between centers and a significant positive relationship between radiation doses and BMI. The Typical DRL value for barium swallow examination was 5.7Gycm2.

Recommendation
I recommend that all imaging centers adopt the established typical DRL, with a regular review of exposure factors in order to optimize radiation exposure.

Keywords: *Typical Diagnostic Reference Level, radiation exposure, optimization.*
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Background
Worldwide, more than 40% of people have functional gastrointestinal disorders which significantly affect the quality of life and health care use (1). Barium studies such as barium swallow is a diagnostic modality used to diagnose gastrointestinal disorders, however, there are concerns about excessive exposure to radiation by both patients and radiation workers (2). Imaging using X-rays contributed the largest part of radiation dose exposure to the human population from man-made sources of radiation, with diagnostic X-rays alone contributing about 14% of the total annual exposure. (3) In a population-based survey in the USA, the prevalence of dysphagia was found to be 16%. (Adkins et al., 2020)

Uganda, in the same vessel as many other African countries had not established DRLs for common radiological examinations like barium swallow as required by the International Commission on Radiation Units and Measurements (ICRU) (4). The absence of DRLs could result in overexposure to radiation which could result in undesired stochastic and deterministic effects to patients and medical personnel. There was a need therefore to develop and implement DRLs as a standardization and optimization tool for the radiological protection of patients undergoing barium swallow studies at the different centers. The specific objective of the study was to determine the Indication-based Typical Diagnostic Reference Level from DAP of patients with dysphagia who underwent Barium swallow examination at the three centers in Kampala Uganda.

METHODOLOGY

Study design

This was a cross-sectional, descriptive, and analytical study.

Study setting

The study was carried out from July 2023 to December 2023 in Kampala at three fluoroscopy centers code-named Study Center 1(a private hospital with a radiology unit), Study Center 2 (a public-private partnership hospital with a radiology unit), and Study Center 3 (a private center that specialized in radiology imaging services, especially fluoroscopy). Kampala is the capital city of Uganda with several tertiary referral hospitals that refer patients for barium swallow examinations to the radiology imaging centers.

Study participants

Patients who weighed 50-90kg, aged 18 years and above, who underwent barium swallow examination at the three study centers were included in the study. These were categorized during analysis into; adult (18-50 years), late adult (>50-65 years), and elderly (>65 years) (5).

Data from patients with incomplete examinations, patients with indications other than dysphagia, and those with poor images (40% score and below) on the image quality rating scale were excluded. Image quality was measured on an attitude rating scale for image quality assessment in fluoroscopy, customized to the study (6).

Sample size estimation

The International Atomic Energy Agency (IAEA) recommends a minimum of ten patients and a maximum of twenty patients per room (7-9). Fifteen patients were chosen considering ten as the minimum number of patients per room. (10)

Since the study was carried out on one examination in three health facilities, sample size = 15x3x1= 45 patients. Being a multi-center study, the sample was doubled to adjust for clustering (11).

The total sample size for the 3 health facilities = x 2
= 90 patients.

Sampling technique

Simple random sampling was used to select three centers out of the available Centers in Kampala that had functional fluoroscopy and were willing to host the study. Consecutive sampling methods were used to select patients at each of the three Health Units to get the required numbers within the available time.

Study variables

The Independent variables were; Patient age, weight, height, BMI, clinical indication, equipment type, model, filtration, secondary radiation grid, and x-ray couch. The Intermediate variables were Fluoroscopic time, Tube voltage (kVp), Tube current (mAs), Entrance Skin Dose (ESD), and Kerma Area Product (KAP) while the Outcome of interest (Dependent variable) was the Indication based Typical Diagnostic Reference Level (DRL).

Data tools and data collection

The principal investigator and the research assistants conducted the data collection using pre-tested questionaries. The protocol followed during barium swallow examinations included; obtaining informed consent from the patient, positioning the patient upright in the anterior and oblique positions with the collimator adjusted to focus the field to the region of interest, giving the patient high-density barium and requesting them to hold it in their mouth until instructed to swallow. This was followed by instructing the patient to swallow gradually as films (frontal, lateral, and obliques) were taken under fluoroscopic guidance. (Sulieman et al., 2018)

The patient's weight, age; height; number of exposures; projections used to acquire images; mill-ampere second; tube voltage; and fluoroscopy time for Barium swallow examinations were recorded. Body Mass Index (BMI) was calculated as weight in kilograms divided by the height in meters squared.

The radiation doses received during Barium examinations were derived by calculating the Estimated Skin Dose and Kerma Area Product using a formula as illustrated below.

Calculation of ESD and KAP

ESD =O x (V/80)2 x(100/d)2CTF, this formula was used where;

- O was the output of the x-ray tube, V was the tube voltage, d was the focus to skin distance, C was the current, T was the exposure time and F was the backscatter factor, 1.37 was used as recommended by IAEA for a particular examination at the required potential. Columns containing parameters in the above formula were created in the data collection and analysis forms.

Columns for: tube voltage V, tube current C, fluoroscopic time T, focus-skin distance d, Current time product, and Field size (Area) were made.

Each row then represents parameters for a single projection which were multiplied to get the ESD and KAP for a single projection, the addition of ESDs and KAPs for several projections of the same patient gave the total ESD (T- ESD) and total KAP (T-KAP) for that patient in Gycm2.

Data Management and Analysis

Data from questionnaires was entered into an Excel sheet. Data cleaning was done and then data was transferred to Stata version 17.0 (Stata corp) for analysis, data was also checked for normality using the Shapiro–Wilk test. Data

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was summarized using descriptive texts, tables, and graphs. Bivariate analysis was done using simple linear regression and this was fitted to get crude coefficients. All the study variables with a p-value of <0.2 at the bivariate level and those known to affect radiation dose were entered into a multiple linear regression to determine the independent factors that influence radiation dose. Confounding was determined if there was a >10% change in the adjusted and crude coefficients for each variable. The level of significance was assessed at a 95% confidence interval and a P-value of less or equal to 0.05. A parsimonious model with the highest R^2 test was considered. The 50th percentile of the radiation doses was calculated as the Indication-based Typical Diagnostic Reference Level.

Quality control and quality assurance

Quality assurance tests were performed by the medical physicist on all the fluoroscopic equipment at the three centers before starting the study and these included; kVp accuracy, beam alignment, and Radiation dose output.
Data was collected using a pre-coded and pre-tested data collection tool. The research assistants were adequately trained and routinely supervised by the principal investigator to ensure the correct use of the data collection tool and adherence to ethical principles. The completed abstraction forms were checked and verified with the data from the machine for completeness and accuracy by the principal investigator.

Ethical considerations

Before data collection, approval was granted by the radiology department of Makerere University College of Health Sciences, Institutional Review Board (IRB) of the School of Medicine (Mak-SOMREC-2023-552), and administrative clearance from the various study sites.
Written informed consent was sought from all the study participants, patient data such as weight was always recorded during routine care, and informed patient consent was obtained for the examinations before they were done.
The study participants were free to withdraw from the study at any time. The research procedure and purpose were explained to the patients in their preferred languages of communication.

Study results

Demography of study participants.

Figure 1 Flow diagram for recruiting participants into the study.

CATEGORY	NUMBER
Eligible	All patients were referred for barium-swallow examination.
Assessed	All patients were referred for barium-swallow examination.
Confirmed eligible	99
Examined	99
Included in analysis	90
Exclude from analysis	9

Excluded due to incomplete exam	5
Excluded due to unclear indication	3
Exclude due to poor-quality images	1

There were no study participants younger than 19 years and the mean age was 48 years with a standard deviation (SD) of 17 years and the range 19-90 years. (Table 1)

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Table 1: The number of study participants 18-50 years, >50-65 years and >65 years of age (N=90). Narrative: Most participants were aged 18-50 years.

Age (Years)	Frequency	Proportion
18-50 (adult)	51	56.7
51 to 65(late adult)	24	26.7
>65(elderly)	15	16.7
Total	**90**	**100**
The mean, standard deviation, and ranges of the ages of the participants		
Mean ±SD	(48±17)	
Range	19-90	

Source: Data from study Centres 1, 2 and 3 (N=90).

Exposure factors (kVp, mAs, and fluoroscopic time) for patients with dysphagia who underwent Barium swallow examination at the three centers in Kampala Uganda

The overall mean kVp for the 3 centers was 69.4Kv with a standard deviation of 6.5. There was a statistically significant difference in the mean kVp between the 3 centers (p-value=<0.001*)* with center 3 having the highest mean kVp of 74.1Kv and center 2 having the lowest mean kVp of 65.2Kv.

The overall mean mAs for the 3 health facilities was 27.1 mAs with a standard deviation of 12.8, and there was no statistically significant difference in the mean mAs between the 3 Centres (p-value=0.194), as shown in Table 3.

The overall mean Fluoroscopic time for all three study centers was 2.5 minutes with a standard deviation of 0.9. There was a statistically significant difference in the mean fluoroscopic time between the three centers (p-value =0.001), with center 3 having the highest mean fluoroscopic time of 3.2 minutes and center 1 having the lowest mean fluoroscopic time of 1.5 minutes. (Table 2)

The exposure factors were selected by machine operators who used their experience and level of education, it was found that the machine operator in study center 1 held a bachelor's degree in medical radiography with 13 years of experience, machine operators in center 2 held diplomas in medical radiography with 9 and 10 years of experience, the machine operator in center 3 had a bachelor's degree in medical radiography with 30 years of experience. None of the centers had standard protocols for the selection of exposure factors. (Table 4)

Table 2: Tube Voltage (kVp), tube current- time product (mAs), fluoroscopic time for patients with dysphagia undergoing Barium swallow examination at the three centers in Kampala Uganda. Narrative: The differences in mean kVp and mean Fluoroscopic time between centers were statistically significant.

Study Centre	kVp, mean± SD, median (IQR)	mAs, mean± SD, median (IQR)	Fluoroscopic time, mean± SD, median (IQR)
1	68.1±2.3, 68(66-70)	37.8±6.4, 40(32-40)	1.5±0.3, 1.7 (1.3-1.8)
2	65.2±6.0, 66(60-70)	13±4.9, 12 (10-15)	2.3±0.8, 2.3 (1.7-2.9)
3	74.1±5.3	35.1±6.7, 40(32-40)	3.2±0.7, 3.2 (2.8-3.6)
	P-value = <0.001	P-value = 0.194	P-value = <0.001
Overall	69.4±6.5, 69.5 (66-74)	27.1 ±12.8, 32 (12-40)	2.5 ±0.9, 2.6 (1.8-3.2)

Computation of the radiation doses received by patients with dysphagia who underwent Barium swallow examination at the three centers in Kampala Uganda using DAP.

The radiation doses were computed for each study Centre and then all the facilities combined as shown in table 4.

The overall mean of outcome dose area product for all three facilities was 6.4Gycm2 with a standard deviation of 3.2. The median outcome dose area product was 5.7Gycm2 with an IQR of 4.0-8.5.

There were significant differences in the mean outcome dose area product between health facilities (p-value=0.006) with Centre 3 having the highest mean of 8.2Gycm2 and Centre 1 having the lowest mean at 4.0 Gycm2 as shown in Table 3.

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Original Article

Table 3: The mean and median outcome dose area product for patients with dysphagia who underwent Barium swallow examination at the three centers in Kampala Uganda. Narrative: The dose area products had statistically significant differences between centers.

Study Center	Outcome dose area product, mean, median (IQR)
C1	4.0±1.5, 4.1 (3.0-4.7)
C2	5.7±2.8, 5.5 (3.6-7.4)
C3	8.2±3.2, 8.3 (5.5-10.6)
	p-value=0.006
Overall	6.4±3.2, 5.7(4.0-8.5)

Relationship between the calculated radiation doses and characteristics of patients with dysphagia who underwent Barium swallow examination at the three centers in Kampala Uganda at multivariate linear regression analysis as shown in table 4;

AGE: The outcomes doses were 1.2 points lower in patients aged > 65 years compared to those aged 18-50 years but this was not statistically significant (p-value=0.256).

BMI: The outcome doses were 1.6 points higher in patients with a BMI of 25<30 (over-weight) compared to patients with a BMI of <25 (normal weight), and this was statistically significant, p-value=0.024

Table 4: Independent factors associated with outcome dose area product for patients undergoing Barium swallow examination at the three centers in Kampala Uganda.

Characteristic (%)	Adjusted coefficients (95% CI)	P-value
Age		
18-50years (51)	Ref	
51-65years (24)	-0.2 (-1.78-1.45)	0.823
>65years (15)	-1.2 (-3.37-0.91)	0.256
Sex		
Male	Ref	
Female	0.8 (-0.50-2.19)	0.214
BMI		
<25 (49)	Ref	
25<30 (41)	**1.6 (0.21-2.99)**	**0.024**
Number of exposures received	-0.4(-1.12-0.42)	0.367
Number of patients worked on according to radiographer education level.		
Diploma (35)	Ref	
Bachelors (55)	0.4 (-1.10- 1.99)	0.568

Typical Diagnostic Reference Levels from DAP of patients who underwent Barium swallow examination at the three centers in Kampala Uganda.

The overall mean of outcome dose area product for all three 3 facilities was 6.4Gycm2 with a standard deviation of 3.2. There were significant differences in the mean outcome dose area product between health facilities, p-value=0.006 with C3 having the highest mean of 8.2Gycm2 and C1 having the lowest mean at 4. 0Gycm2. The median outcome dose area product was 5.7Gycm2 with an IQR of 4.0-8.5. Therefore, Typical Diagnostic Reference Levels from DAP of dysphagia patients undergoing Barium swallow examinations at the three centers in Kampala Uganda was 5.7 Gycm2 as illustrated in Table 5

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Original Article

Table 5: The mean outcome dose area product for patients undergoing Barium swallow examination at the three centers in Kampala Uganda.

Study centre	Outcome dose area product, mean, median (IQR)
C1	4.0±1.5, 4.1 (3.0-4.7)
C2	5.7±2.8, 5.5 (3.6-7.4)
C3	8.2±3.2, 8.3 (5.5-10.6)
	p-value=0.006
Overall	6.4±3.2, 5.7(4.0-8.5)

Image quality assessment.

Image quality was measured by radiologists on an attitude rating scale for image quality assessment in fluoroscopy, customized to the study (Walsh, Dowling, Meade, & Malone, 2005). Data of patients with poor quality images (40% score and below) on the image quality rating scale was excluded and the rest was included in the study. The image quality results of the study were summarized as illustrated in Table 8 below.

Image quality for the Study Centres.

The overall results indicated that 23 % of all the images had very good quality, 45 % were of good quality and 32% were of satisfactory quality as illustrated in table 6 below. The mean image quality scores for centre 1, centre 2 and centre 3 were 69% and the median quality score was 70%. Centre 3 had the highest mean image quality score (76%) while Centre 2 had the lowest mean image quality score (59%) with a range of 17%.

Table 6: Image quality scores of images from the different Centres. Narrative: The overall image quality was good with a score of 69%.

Grades of image quality	Satisfactory (41-60) %		Good (61-80) %		Very good (81-100) %		TOTAL %	Mean	Median
CENTRES	No	%	No	%	No	%			
C1	9	47	6	32	4	21	100	66	60
C2	20	57	15	43	0	0	100	59	55
C3	0	0	19	53	17	47	100	76	82
C1+C2+C3	29	32	40	45	21	23	100	69	70

NOTE: A total of nine patients had their data excluded from analysis due to incomplete examinations, unclear indications, and poor-quality of images.

Table 7: Comparison of Typical Diagnostic reference Levels from different countries.

	Data source	Country	Typical DRL
1	**The present study**	**Uganda**	**5.7 Gycm²**
2	(25)	UK	3.5 Gycm²
3	Zammit-Maempel, Chapple, & Leslie, 2007)	UK	1.4 Gycm²
4	(26)	Germany	6.1 Gycm²
5	(27)	South Africa	7.2 Gycm²
6	(18)	Brazil	41 Gycm²

DISCUSSION OF RESULTS.

The mean age of patients in this study was (48±17), less than the mean age of 61.2 years and 64.5 years among patients in earlier studies. (12) and (Tristram et al., 2022) respectively. The relatively low average age in the current study is attributable to the predominantly young population in Uganda (13),(2020) when compared to the population of countries like Germany (14), however, this highlights the need to reduce the risk of radiation in a younger population.

Centre 1 had a digital Machine from Siemens Healthcare Center 2 had a digital machine from Genera Medical Marate and Centre 3 had a digital machine from Phillips Medical Systems, all machines had a common generation of modern technology, hence setting uniform grounds for the study and also optimization of radiation exposure. (Roch et al., 2018) .The fluoroscopy machines in this study were digital fluoroscopy machines with flat-pannel detectors, which are the modern type of fluoroscopy machines, that have replaced conventional fluoroscopy machines. (15). All the machines had built anti-scatter

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Original Article

grids and x-ray tubes above the table as was the case in earlier studies by Hayes et al (2009). The anti-scatter grids are of advantage in that they prevent scatter radiation from reaching radiation workers while the uniformity of fluoroscopy machines makes comparison of studies possible. There were no KAP meters to directly measure radiation doses from the machines, thus, the Estimated Skin Doses from the machines were calculated using an acceptable formula, and then ESDs were multiplied by field size to get, the DAPs (16)

The overall mean kVp for the 3 centers was 69.4 Kv with a statistically significant difference in the mean kVps between the 3 centers (p-value=<0.001*)*. The mean mAs between the centers in this study were different, however, this was not statistically significant. There was a statistically significant difference in the mean fluoroscopic time between the 3 centers (p-value =0.001), The findings in this study were similar to an earlier study by Zila et al (2018) to the extent that the exposure factors (kVps. mAs, and fluoroscopic time) were different between centers. The differences in the exposure factors were due to differences in experience and training level of staff but also due to the absence of standardized protocols.

The overall mean of outcome dose area product for all three 3 facilities was 6.4Gycm2 with a standard deviation of 3.2. This is lower than 9.3Gycm2 which was found in Western Cape-South Africa (Peters, 2017). It is also lower than the value found out in an earlier study conducted in north-eastern Nigeria (17) where the overall mean DAP was 7.62Gycm2 with a standard deviation of 2.01. This is because the exposure factors (overall mean kVp and overall mean mAs) which have a direct relationship with the dose were also higher (72.5Kv and 37mAs) in the earlier study by (17) than in the current study (69.4Kv and 27.1mAs). It was also lower than 37Gycm2 in a study by (18) probably because more mean time of 6.1 minutes was used compared to the 2.5 minutes observed in this study.

Whereas the differences in mean radiation doses between the centers were not statistically significant in the study by Zira et al. (17), the differences in mean radiation doses between centers in this study were statistically significant (p-value=0.006), this was probably because the exposure factors (kVp, mAs, fluoroscopic time) which impact the radiation doses also had significant differences between centers in this study whereas not in the earlier study.

The radiation doses received by clients were higher in females than males, however, there was no statistically significant relationship (p=0.091) between sex and the radiation doses received by patients, this is similar to what was observed in earlier studies by (19)and (20)). These findings are explained by the fact that women tend to have a higher BMI when compared to males (21), which translates into higher radiation doses.

The radiation doses increased as BMI increased from normal to overweight and this relationship was statistically significant (p=0.002) as likewise observed in a study by Kim et al (2013). This is because as the BMI increases, the thickness of the tissue to be penetrated by the radiation increases thus the need for a stronger penetrating power (kVp) and more photons (mAs) of the radiation beam which translate into delivering more energy (radiation dose) to the patients.

The radiation doses received by patients decreased as the age of the patients increased, especially among the elderly, however, this was only statistically significant (p= 0.023) in bivariate analysis. This implies a negative correlation between age and radiation doses, which was also observed in a study by (22). This is probably because as most people tend towards late adulthood they tend to have lower weights(23),(24), (due to reduced ability of the body to regenerate new tissues, comorbidities like cancers, etc) and thus lower BMI which translates to lower radiation doses as per the relationship observed between radiation doses and BMI in this study.

The established Typical Diagnostic reference level was found to be higher than the Typical Diagnostic reference levels for England but less than the Typical Diagnostic Reference Level from Brazil, South Africa, and Germany. The median outcome dose area product was 5.7Gycm2 with an IQR of 4.0-8.5. Therefore, the Typical Diagnostic Reference Level of dysphagia patients who underwent barium swallow examinations at the three centers in Kampala, Uganda was 5.7Gycm2.

The established Typical Diagnostic reference level (5.7Gycm2)was found to be higher than the Typical Diagnostic Reference Levels for England, (Crawley et al., 2004). This is probably because, in the earlier studies, there was no need for taking spot images which explains the low doses despite longer fluoroscopic time. The established Typical diagnostic reference level (5.7G**y**cm2) was lower than the Typical diagnostic reference level from South Africa (7.2 Gycm2), Brazil (6.1 Gycm2), and (Germany 41 Gycm2) probably because these studies had smaller sample sizes which were less than half of the sample size in this study. This situation could have resulted in relatively higher Typical diagnostic reference levels due to the effect of outliers as demonstrated in a study by (27), it's also known that the tendency of outliers to inflate results increases as the sample sizes decrease (28) hence the effect of outliers is more significant in smaller sample sizes when compared to larger sample sizes.

It is important to note that this study lacked a perfect match for a more objective comparison as there were significant differences in study designs when compared to most of the earlier studies, all the earlier studies had a smaller sample size and none of them assessed image quality.

The overall result (Table 6) indicated that the average quality score for all the images was 69% Whereas study center 3 had the highest contribution of quality images with an average quality of 76%, it also contributed the highest radiation dose with an average DAP of 8.2mGycm 2. This is so probably because achieving high-quality images with very good contrast, sharpness, and without image noise requires high exposure factors which directly contribute to a high radiation dose received by patients as observed in this study where study centre3 had higher mean exposure factors (table 1) than the other centers.

This observation matches the findings of Sulieman et al (2015) where exposure factors were observed to directly affect radiation dose (radiation dose increased as exposure factors increased) (29). The findings in this study also demonstrated that Study Center 1 and Study Center 2 which had lower mean image quality scores than Study Center 3 (table-6) also had lower mean radiation doses than Study Center 3 (table-2), which findings resonate well with the fact documented by Andreozzi et al (2020), that image quality degrades with lowering of radiation dose.

Generalizability; The findings of this study have good generalizability with respect to patients with dysphagia since participants were from both private and public settings.

Conclusion

There was a significant positive relationship between radiation doses received by patients and the BMI. There was also a significant difference in the exposure factors between the different Imaging centers.

The patient indication-based Typical DRL values for barium swallow examination have been established in Uganda for the first time and also found to be higher than the Typical DRLs in the United Kingdom but lower than the Typical DRLs in South Africa, Germany, and Brazil. The findings have laid a foundation for understanding the status of fluoroscopic radiation doses received by particular patients undergoing particular examinations.

Limitation to the study

There were no KAP meters for all the centres hence manual methods were used to calculate the dose area product.

Recommendations

I recommend that all imaging centers adopt the established typical diagnostic reference level, with a regular review of exposure factors to optimize radiation exposure.

I recommend that the Atomic Energy Council should ensure that only machines with KAP meters are installed in the different facilities.

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Conflict of interest

There was no conflict of interest in this study.

List of abbreviations

AEC: Atomic Energy Council (AEC)
ALARA: As Low as Reasonably Achievable
BMI: Body mass index
DAP: Dose-Area Product
DRLs: Diagnostic Reference Levels
ESD: Entrance Skin Dose
Gycm2: Gray square centimeters
ICRP: International Commission for Radiological Protection
IRB: Institutional Review Board
KAP: Kerma Area Product
KERMA: Kinetic Energy Released per unit Mass of Air
KVp: kilo voltage peak
MAs: milliampere second
MNRH: Mulago National Referral Hospital
WHO: World Health Organization

Consent of publication

I consent to publication.

Availability of data and material

All data generated and/or analyzed during this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

KS- conceptualized the idea, collected data, participated in the analysis, and drafted the first manuscript; EG- refined the initial idea, assisted with data interpretation, and participated in critical editing of the paper; NR and AM- contributed to refining the idea, technical guidance on the methods and interpretation of the study findings; ZL- participated in data analysis and interpretation of findings; AF, NV, and TJ assisted with image quality assessment and quality assurance.

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