Abdominal imaging ORIGINAL ARTICLE

Hysterosalpingography dose assessment with direct digital radiography in a medical facility: A potential high risk procedure to patient in South-South Nigeria

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ABSTRACT

Background: Hysterosalpingography (HSG) procedures often come with higher doses due to multiple exposures.

Aims: The study was aimed at carrying out a preliminary audit of doses in HSG exams with thermoluminescent dosimeters (TLDs) in a facility using direct digital radiography (DDR), with the aim of identifying parameters that greatly affect the patient dose and see possible ways to optimize them in the future

Methods: The prospective study involved 53 booked female patients for HSG procedures. The study used a ceiling-mounted direct digital radiography unit for exposures. The patient was made to lie in a supine position. Two TLD chips (LiF: Mg, Ti) were positioned at the central axis of the beam covering the pelvis to estimate the entrance surface dose (ESD) and another posteriorly to estimate the exit dose (ED). A PCXMC software was used to estimate the effective dose (E_{ff}) and organ doses.

Results: The mean and 75th percentile ESD was 15.94±2.05 and 18.82±6.41 mGy respectively. The number of exposures, dose area product (DAP), and effective dose (E_{ff}) ranged from 5.7 (4-10), 15.85 (5.02-51.07) Gycm^2 and 4.6 (1.46-14.8) mSv. The mean dose to the ovaries, uterus, and bladder were 4.63 (4.06-5.03) mGy, 6.17 (5.45-6.65) mGy, and 10.8 (9.68-11.92) mGy. The es-

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timated cancer risk was 230 (90-740) per million.

Conclusion: The ESD, $E_{ff,}$ and organ doses were comparable to studies that used TLDs with conventional radiography; however this study was multiple times higher compared to the fluoroscopy modality. Factors that contributed to patient dose were the number of exposure and patient field sizes. Protocol optimization should be considered to reduce patient risk.

KEY WORDS

Hysterosalpingogram; Organ dose; Thermoluminescent dosimeter; Exposure; Conventional radiography

Introduction

The hysterosalpingography (HSG), or uterosalpingogram, is an X-ray examination of a woman's uterus and fallopian tubes [1, 2]. The common indication for hysterosalpingography is either primary or secondary infertility and it is estimated that 90% of these patients are referred for this procedure [3]. This type of X-ray is normally performed with fluoroscopy and a contrast agent, however, in many developing countries with protracted fluoroscopy downtime, conventional imaging is still heavily employed [4-6].

The use of conventional film screen in HSG has been reported to be higher compared to the use of fluoroscopy systems [7-9], while the effective dose (*E*) and the lifetime cancer risk have been found to be multiple times higher [10, 11]. A study by Papaioannou et *al*, have raised safety concern about women who have done the procedure multiple times, indicating that they may be at higher cancer risk [12].

The use of appropriate technical factors (kilovoltage (kV) and milliampere seconds (mAs)), optimized protocols with respect to the X-ray equipment, and the expertise of the radiographer/operator area contributory factor to patient doses [13, 14].

Measurement of dose in HSG could be through the kerma-area product (KAP). The KAP represents the dose (in mGy, cGy, or Gy) at the center of a certain plane of the X-ray beam in the air. The amount of radiation received by the patient from the X-ray machine is multiplied by the area of the X-ray field at that plane. Generally, KAP is expressed in units of Gy. cm^2, $mGy.cm^2$, or $\mu Gy.cm^2$ [15]. KAP is usually measured using a transparent flat ionization chamber mounted in the X-ray tube assembly between the collimators and the patient. This approach is used in conventional radiography and in some mini C-arm fluoroscopy systems. In most fluoroscopic machines, the KAP chamber is hidden by the tube-housing cover. Some fluoroscopy machines calculate KAP using generator and collimator settings [16].

Thermoluminescent dosimeter (TLD) and optically stimulated luminescent dosimeter (OSLD) have been used to estimate the entrance skin dose (ESD) and can be converted to estimate the dose area ($mGy.cm^2$) by taking note of the field size after the collimator knobs (and y planes) have been adjusted prior to exposure or using a gafchromic film to measure the field size. [17]. In addition, the silicon photodiode has been used to determine the dose-area product (DAP) but mostly with phantom studies [18, 19]. It should be noted that the term KAP and DAP are used interchangeably. KAP or DAP can provide a good estimate of stochastic risk, but it is not directly useful for estimating tissue reactions [20].

The study was aimed at using TLDs with a ceiling-mounted direct digital X-ray system (Carestream) to estimate the ESD (mGy), DAP ($Gy.cm^2$), E_{ff}, and organ doses from HSG procedures. Furthermore, results from this study were compared to the use of radiography (film screen) and fluoroscopy systems.

Materials and Methods

The retrospective study involved 53 female patients who were referred for HSG in the radiology department of a medical center. They were divided into 3 groups: 21-30, 31-40, and 41-50 years respectively. This study involved four qualified and experienced radiographers, 2 consultant radiologist, and 2 medical physicists with adequate working experience. A direct digital Radiography system (Carestream Health, Inc. Rochester, NY 14608 United States) was used with the inherent grid system (Table 1).

Table 1. Digital radiography specification

Digital radiography equipment specifications	
Manufacturer	CARESTREAM
Type	Ceiling Mounted Unit (DR System)
Machine Model	18H1896
Serial Number	GQ50-18R-10022
Power Capacity	70kW
Maximum Tube Voltage	150kVp
Maximum X-ray Tube Current	1000 mAs
Total Filtration	3.3mmAl
Anode	Rotating Anode X-ray Tube Assembly
Electrical Circuit	High Voltage Generator
Line Voltage	115-240V
Phase/Frequency	3φ, 50/60/150/180Hz
Target	Tungsten
Date of Manufacturer	July, 2018
Country of Make	China
Date of Installation	May, 2020

Each patient gave their consent before the commencement of the procedure. Patient weight and height were measured using a stadiometer and a weighing balance. Similarly, the patient was made to lie in a supine position on the table bucky to measure the pelvic thickness. The study used MTS-N chips (LiF: Mg, Ti) as described (Table 2).

The TLD chips were positioned at the central axis of the beam in the pelvic region after collimation by the radiographer and the second was positioned at the same point posteriorly. The TLD chips were used to estimate the entrance surface dose (ESD) and the exit dose (ED) respectively.

In other to effectively use the TLD chips, they were first annealed in a TLD Furnace Type LAB-01/400 at a temperature of 400℃ for one (1) hour and were allowed to cool to room temperature. To remove lower peaks they were heated to a temperature of 100℃ for another two (2) hours and were put to use after 48 hours. Parameters like the element correction factors (ECF) (0.9-1.1) and homogeneity of the TLD chips (< ±30%) were found to be within the acceptable range for the patient dose measurements and were in line with published articles [21].

Table 2. TLD (LiF: Mg, Ti) specification

Detector features	
Detector type	MTS-N
Phosphor	LiF:Mg,Ti
Batch no	RS 2146/19
Dimensions/Diameter	φ 4.5mm
Thickness	0.9± 0.05 mm
Sensitivity spread	± 3.5% SD

A RadPro Cube 400 manual TLD Reader (Freiberg Instruments GmbH, Germany) was used to determine the corresponding TLD count for the chips. The average background count was obtained from three TLD chips that were not exposed to radiation (TL_0). Obtained TL counts ($TLi-TL_0$) were multiplied with a pre-determined X-ray calibration factor using the following equation [22, 23]:

$$ESD = (\mathrm{TL}_i - \mathrm{TL}_0) \times \mathrm{CF}_{\mathrm{X-ray}} \left(\mathrm{mGy}/_{\mathrm{count}}\right) \quad [1]$$

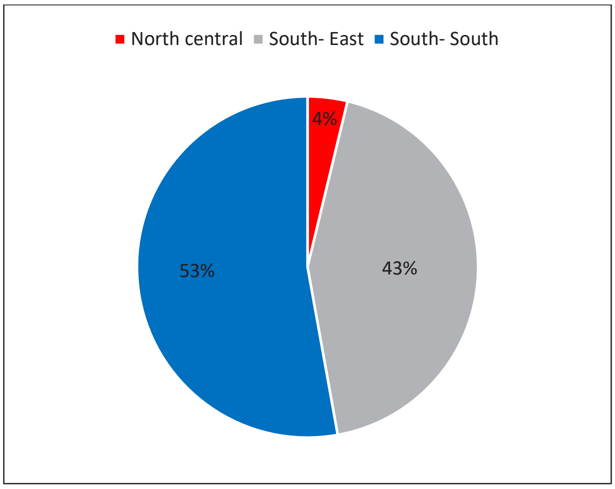

__Figure 1:__ Distribution by region for HSG (womb X-ray)

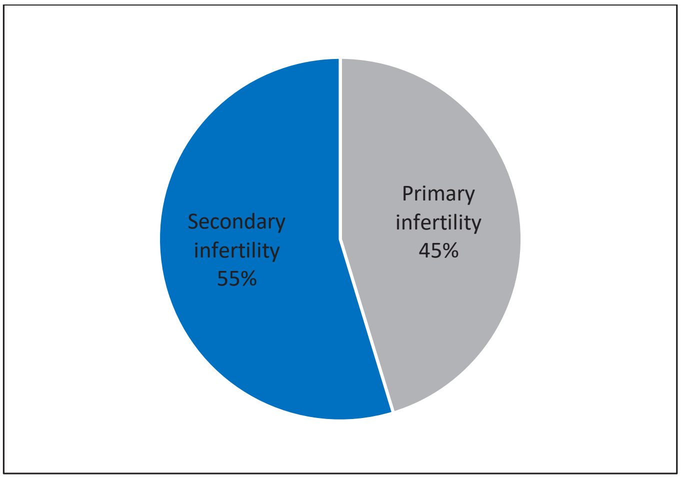

__Figure 2:__ Percentage clinical information of the patients for HSG (womb X-ray)

Where $TL_{i=1,2,3...}$ is the count from the selected chips, TL_0 is the background count, CF is the calibration factor of the TL chips with the X-ray equipment. The calibration process was done in the air at 80kV. Verification of the accuracy of the energy used was done with a silicon photodiode and a current probe meter was used alongside a MagicMax basic unit (IBA Dosimetry, Germany), which has the capacity to measure practical peak voltage (PPV), mAs, mA, exposure time, dose (mGy) and dose rate simultaneously.

The DAP was estimated using the relation [24]:

$$\mathrm{DAP} = \frac{ESD}{BSF}\ A(FSD) \qquad [2]$$

Where the BSF was the backscatter factor. The assumed BSF (PMMA) was 1.52 (625cm^2) at 80kV and filtration of 3.0 mmAl for the maximum field size, based on the International Atomic Energy Agency TRS 457 report [17] and *A* (*FSD*) was the area of the field size for individual focus to skin distance.

The patient's effective dose (*E*) was determined using the mathematical relation [25]:

$$\text{Effective dose } (E_{ff}) = DAP \times F_h \qquad [3]$$

Where F_h is the conversion factor for the pelvis, which was 0.29 [11, 25, 26].

In addition, PCXMC software was used to estimate the organ dose to the ovaries, uterus, and bladder by plugging in the average patient age, FSD, body mass, height, kVp, and field size to the PCXMC spreadsheet.

The excessive lifetime cancer risk was adapted from the ICRP 60 report, where the risk factor was 5×10^{-2} Sv^{-1}[27].

Results

There are 6 geo-political zones in Nigeria and the result shows that half of the zones took part in the procedure. The highest was in the South-South, where the facility was located (Figure 1).

Also, the study shows that most women who came for HSG had secondary infertility, indicating that at one point or the other, they had conceived and given birth (Figure 2). Images of the procedure for the prelim stage, injection of contrast to visualize the uterus and the tubes, and delay images (Figure 3).

The maximum patient thickness was within 31-40 years (33cm) and the focus to skin distance (FSD) ranged from 93-128 cm, while the maximum field size was 1849cm^2. The maximum number of exposure was 10, while the mean was approximately 6 exposures per patient. Pearson's correlation shows that there was a direct relationship between patient thickness with field size ($P < 0.001$), kVp ($P < 0.001$), mAs ($P < 0.001$), and the number of exposure ($P < 0.001$), the results were statistically significant. Also, there was a good relationship between focus to skin distance (FSD) versus kVp ($P = 0.008$) and mAs ($P = 0.010$) but no relationship was seen against ESD ($P = 0.184$) and AD ($P = 0.119$) (Table 3 and 4).

Furthermore, the ESD among the age groups progressively increased. This was also the same for the DAP and

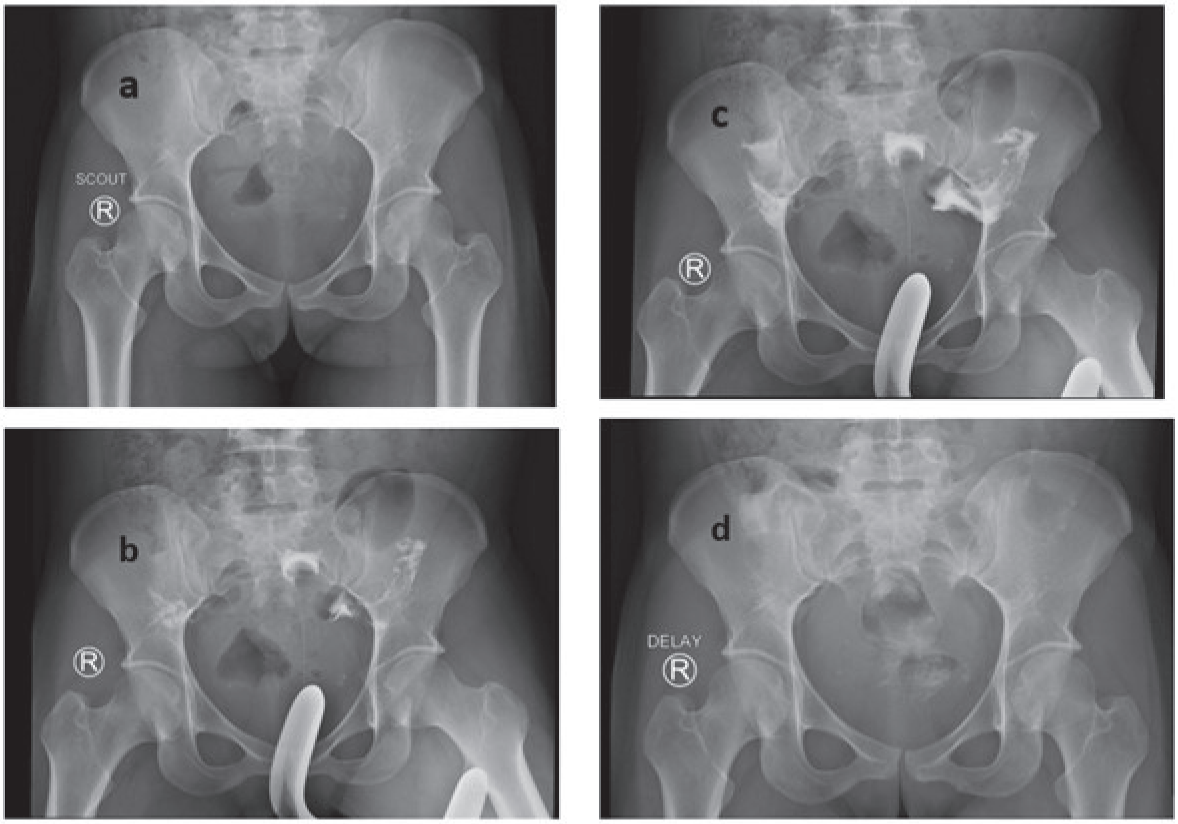

Figure 3: *HSG procedure with digital radiography (a) Scout image, (b) build-up of contrast in the uterus, (c) visualization of the uterus and tubes (d) delay image*

effective dose (E_{ff}) respectively. The least absorbed dose (AD) was between the ages of 31-40 years (0.4 mGy). Pearson's correlation shows that there was a direct relationship between the patient's field size and ESD ($P < 0.001$) and AD ($P < 0.001$) respectively (Tables 3 and 4).

The number of patients for the procedure, age, body mass index (BMI), screening time, number of exposure, ESD/75th percentile, DAP, and the effective dose were compared with similar articles. Fluoroscopy and radiography were the modalities used, while the estimation of the patient dose was through the use thermoluminscent dosimeters (TLDs) and mathematical software. The table show some similarities and variation across different authors with digital fluoroscopy, film-screen radiography, analog fluoroscopy, and direct digital radiography respectively (Table 5).

The DAP (Gycm^2) and Effective dose (E_{ff}) in this study were compared to the National Radiological Protection Board (NRPB) and the National Council on Radiation Protection and Measurements (NCRP) reports. Both reports appear to present the same data (Figure 4)

In addition, organ doses were compared for the ovary, uterus, and bladder among the age groups in this study (Figure 5). It was also compared with several published articles, where different calculation methods were used (Table 6).

Discussion

The study has determined patients' doses from HSG procedures using direct digital radiography. The use of conventional radiography for interventional studies is still a challenge in developing countries like Nigeria, where the management of fluoroscopy systems is poor, hence more downtime. This study has shown that patients received higher doses compared to the use of fluoroscopy.

The mean DAP from this study was 4 and 9 times the NRPB/NCRP 160 report and Heath Protection Agency

Table 3. Mean/mean total of patient and radiography parameters based on age groups

N	Age (years)	Thickness (cm)	FSD (cm)	Field Size (cm^2)	Weight (Kg)	Height (m)	kVp	mAs	No of exposure
10	29.3 (21-30)	21.5 (17-29)	106 (93-128)	1619 (1155-1849)	74 (54-115)	1.65 (1.56-1.73)	75 (70-80)	22.7 (16-40)	5.4 (4-7)
35	34.5 (31-40)	23.2 (16-33)	107 (100-116)	1507 (1050-1849)	69(47-90)	1.61 (1.01-1.72)	75 (65-80)	22.6 (16-40)	5.6 (4-8)
8	42.4 (41-50)	21.3 (18-25)	104 (100-105)	1431 (925-1849)	76 (64-100)	1.59 (1.51-1.70)	76 (70-80)	23.3(12.5-32)	6.3 (4-10)
53	34.7 (27-48)	22.61 (16-33)	105.7 (93-128)	1517 (925-1849)	71 (47-115)	1.62 (1.01-1.73)	75 (65-80)	22.7 (12.5-40)	5.7 (4-10)

Table 4. Mean/mean a total of dose indicators based on age groups

Age (years)	ESD (mGy)	AD (mGy)	DAP (Gycm^2)	E_{ff} (mSv)
29.30 (21-30)	14.19 (10.4-16.21)	8.89 (2.65-14.2)	15.12 (7.90-19.71)	4.38 (2.29-5.72)
34.49 (31-40)	15.43 (7.26-26.76)	6.63 (0.4-16.3)	15.30 (5.02-32.56)	4.44 (1.46-9.44)
42.38 (41-50)	18.20 (10.38-41.98)	9.04 (1.1-19.6)	17.13 (6.32-51.07)	4.97 (1.83-14.81)
35 (27-48)	15.94 (7.26-41.98)	8.19 (0.4-19.6)	15.85 (5.02-51.07)	4.60 (1.46-14.81)

(HPA-CRCE-034) report United Kingdom (UK) [11, 26, 28], while the E_{ff} was 4 times higher compared to the NRPB/NCRP 160 report, where fluoroscopy systems were used [11, 26]. Some of the reasons for this unusually high value are the number of exposure per procedure, patient field size, and FSD. Field size reduction and FSD have been identified as tools to reduce patient dose [11]. The study identified a direct relationship between the number of exposure and the ESD ($P < 0.001$), which is known to be directly proportional to the DAP and E_{ff}. Also, the field size had a direct relationship with the ESD ($P < 0.001$). Findings from this study show that patient dose is mostly affected by the number of exposure per case and the field sizes. Another factor considered may be due to the experience of resident doctors and intern radiographers handling HSG procedures [29-31]. In addition, there was no statistically significant difference between the calculated and PCXMC software for the age groups ($P < 0.05$), proving the calculated approach was accurate.

The mean ESD from HSG procedures with conventional radiography with TLDs by Achuka et *al*, in South-West Nigeria (21.36 mGy) and Alzimami et *al* in Sudan (23.16 mGy) were higher compared to this study, with a variation of 20 and 26% respectively [32, 33] while it was lower compared to Khoury et *al* but with a variation of 17% [34]. Similarly, the mean ESD from conventional radiography studies in Romania with TLDs by Iacob et *al* (57 mGy) and Sudan with DoseCal software by Yousef et *al* (20.9 mGy) were higher compared to this study with a dose variation of 79 and 18 % respectively [35, 36]. It can be deduced that the maximum variation between direct digital (this study) and film screen systems was 26%, based on the above comparisons. The Health Protection Agency (HPA) report 34 from the United Kingdom by Hart et *al* from 84 hospitals and 9132 adult patients have indicated that the mean and maximum value from a single pelvic (AP) X-ray was 3.2 and 8.3 mGy respectively. By translating this into HSG investigation, we notice that a mean and maximum number of exposure of 5.7 and 10 (from this study), will produce approximately a dose of 18 mGy and 47 mGy respectively. This confirms the study's validity with TLDs, where the maximum dose was 42 mGy. Furthermore, this study measured an ESD of 2.8 mGy per exposure. A similar ESD was reported in HPA report 34, which was 2.9 mGy for the pelvis. Basically, HSG with radiography is a multiple pelvis exam. Image intensifiers and flat-panel fluoroscopy systems with interven-

Table 5. Comparison of this study with similar articles/publications

Authors	n	Age (yr)	BMI (kg/m^2)	Screening time (min)	No of exposure	ESD/75th Percentile (mGy)	DAP (Gycm^2)	E_{ff} (mSv)	Modality
This study	53	35 (27-48)	27(17.4-43.9)	-	6 (4-10)	16 (7.3-42)/19	15.9 (7.9-51)	4.6 (1.5-14.8)	FPDR
[8]	40	-	-	0.7	3.6	13.3 (0.5-38.6)	-	-	AF
[11]	-	-	-	-	-	-	4	1.2	DF
[26]	4248	32(18-95)	-	0.63 (57^a)	4 (1-86)	-	1.7	-	DF
[32]	80	-	-	-	-	21.36	-	-	CR/FSR
[33]	-	-	-	-	-	13.6-35.7		2.1-4.3	FSR
[34]	25	21-45	-	-	4-15	12.6 (4.99-36.6)	-	-	FSR
[35]	1050	-	-	-		57.4±23.5		6.6±2.7	FSR
[36]	50	24-43	27.27	-		20.9 (9.5-42.5)	-	1.94	FSR
[37]	21	32 (24-39)	-	15 (5-45)	2 (2-4)	14.6(1.4-46)	-	-	AF
[38]	37	34 (20-43)	42 (20-31)	18.2 (6-66)	6 (3-9)	3.6 (0.7-8.2)	-	-	DF
[39]	-	27 (18-27)	-	0.3	3.2	9.7	-	1.2	DF
[40]	87	32 (21-49)	-	2.1 (0.2-5.5)	8 (3-21)	-	2 (0.5-16)	0.6 (0.1-5)	DF
[41]	34	20-40	-	58 (210^a)	-	-	5.62 (23.2^a)	1.39 (8.53^a)	FSR
[42]	62	19-54	-	-	-	-	4.1-6	-	DF
[43]	-	-	-	0.8^b	5	1.6-2.8^b	2.2^b	0.65^b	DF
[44]	41	33 (26-42)	-	0.5	7	-	7.1 (2.5-16)	3(1-8)	DF

FPDR = Flat Panel Digital Radiography, AF = Analog fluoroscopy, DF = Digital fluoroscopy, FSR = Film screen radiography, CR = Computed Radiography. a = maximum values, b = median value

tions have been developed to minimize the patient's overall dose [28].

Differences in ESD were due to the acquisition methods (digital versus analog), technical factors, the experience of the radiographer/operator, and uncertainties from the TLDs used, among others. The range of the ESD with analog fluoroscopy in combination with standard film-screen radiography units from a study by Gregan et *al* was higher with a variation of 6% in the mean ESD against this study [37]. Similarly, Fife et *al* used the same approach (film-screen and analog fluoroscopy) and the mean ESD varied by 13% compared to this study [8]. The comparison between the direct digital radiography in this study with analog fluoroscopy systems was < 20%. However, the patient dose from direct digital radiography in this study was 4.4 and 1.7 times higher in ESD compared to Suleiman et *al* and Perisinakis et *al*, with a wider variation in dose [38, 39].

Direct digital radiography (DAP) in this study with direct digital radiography was 2-8 times higher compared to digital fluoroscopy studies [40-44]. The associated error may occur during ESD-DAP conversion in this study, and this may affect the overall DAP also the TLDs used were point sources and may not compensate for dose distribution against the use of scintillators and silicon photodiodes in digital fluoroscopy. The E_{ff} in this study was 1.5-8 times higher than studies with fluoroscopy [39-41, 43, 44], raising the need for protocol optimization despite that the mean ESD per radiograph was in line with published values. A study by Maataoui et *al* noticed that there was no significant difference in screening time between analog

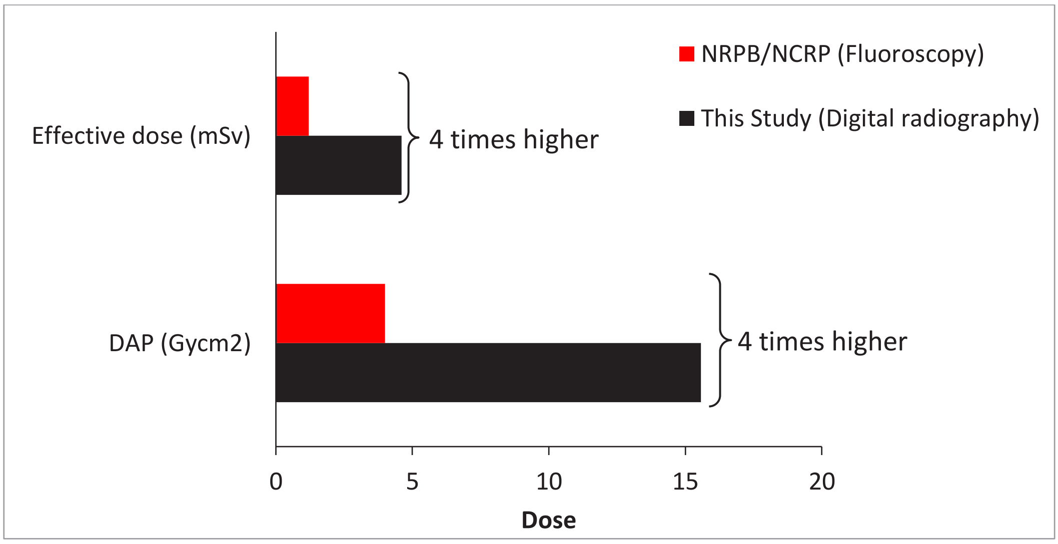

Figure 4. *Comparison of effective dose and DAP between this study (digital radiography) and the NRPB/NCRP report (fluoroscopy)*

and digital fluoroscopy systems but variation in patient dose was noticed, which is likely due to recent advances to reduce patient dose through the use of more sensitive detectors for imaging [45].

The organ dose software in this study was similar to those used by Achuka et al where the study used computed radiography (CR) and film screen radiography (FSR) to determine patient doses. The range of the organ dose for the ovaries, uterus, and bladder was comparable to this study [32]. Also, the organ dose to the ovaries from a study by Hedgpeth et *al* was comparable with this study with different organ dose calculators. The variation in organ dose was 1.08% [46], while it was lower compared to a study by Nakamura et *al*, where the ovary dose has doubled this study [47]. Dose to the ovaries from a study by Kramer et *al* with phantom simulation (Monte Carlo MIRD) was higher compared to this study [48]. Some of the discrepancies in organ doses could be due to patient parameters (kVp, mAs, field size, FSD) inputted into the software spreadsheets.

The ICRP-60 excessive lifetime risk due to exposure from low LET radiation was 5×10^{-2} Sv^{-1}. We can deduce that the mean/range associated with a patient undergoing HSG was 230 (90-740) per million. The risk in this current study was higher compared to the work on HSG patients by Papaioannou et *al*, with a digital fluoroscopy system. The excessive lifetime risk was 4-13 per million, indicating that this study's risk was far higher [12]. The risk from HSG for 21-30 years in this study was 219×10^{-6}, it was found to be higher compared to the United States (US) and United Kingdom (UK) risk from HSG, which was 145×10^{-6} [49] and 86×10^{-6} [50] for 20-29 years from a study by Perisinakis et *al* [39]. The risk from this study was 1.5 and 2.5 higher compared to both reports.

There is a critical need for protocol optimization since the use of conventional radiography for interventions is common in Nigeria. The study has discovered crucial factors like the number of exposures, FSD, and field size that should be decreased without significantly compromising image quality. Magnetic resonance imaging (MRI) - Hysterosalpingography and Sonohysterography have many advantages such as not using radiation, less pain, and maximum analysis of pelvic anatomy. The combination of both methods leads to optimized visualization, less procedures and less exposure to radiation.

Conclusion

Dose measurements for HSG procedures with DDR were multiple times higher compared to standard fluoroscopy systems. Major factors contributing to patient dose were the number of exposures, focus on skin distance (FSD), and field size. Although, the study compared well with film-screen radiography in other studies. The

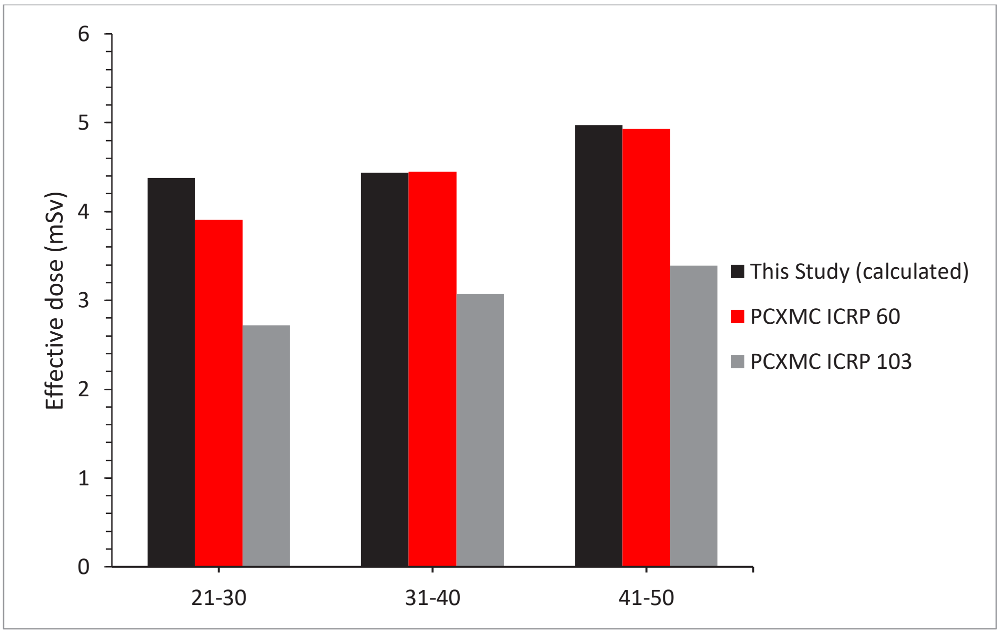

Figure 5: *Comparison of effective dose with PCXMC software*

Table 6. Comparison of organ dose with different calculation methods

Authors	Ovaries	Uterus	Bladder	Calculation method
This study	4.63 (4.06-5.03)	6.17 (5.45-6.65)	10.8 (9.68-11.92)	PCXMC software
[9]	2.8	-	-	-
[32]	2.81-5.54	3.49-6.95	7.23-14.68	PCXMC software
[34]	2.94	4.03	-	MC EVA based CCs
[36]	3.53	4.8	-	DoseCal software
[37]	3.4	-	-	-
[38]	0.91	-	-	NRPB MC calculation
[39]	2.7	-	-	TLD with Phantom
[41]	2.7	4.06	-	NRPB MC calculation
[43]	1	1.6	4	PCXMC software
[46]	9	-	-	-
[47]	4.56	3.83	-	MC MIRD5 based CCs
[48]	8.5	-	-	MIRD5-type EVA phantom

MC = Monte Carlo, CCs = Conversion coefficients lifetime risk of cancer is likely to increase due to the number of exposure per exam. Protocol optimization and the use of trained radiographer and radiologist for HSG procedures will further reduce the total number of dose/exposure. **R**

Declarations

Ethics approval and consent to participate:

This study was approved by the ethics committee of Federal Medical Centre Asaba with approval number FMC/ASA/A102 VOL. XV/A132. Written informed consent was obtained from each patient before the commencement of the study

Consent for publication:

"Approval for publication was granted"

Availability of data and material:

The data sets used and/or analyzed during the current study are available from the corresponding author on request.

Competing interests:

No competing interest Funding:
No funding whatsoever

Authors' contributions:

"ADO conceived the topic and made provisions for the materials used for the research. He designed the template for data collection, did the TLD readout, data analysis, manuscript preparation, and manuscript editing. AAA/KBU/EOO did literature search and he also edited the manuscript for possible errors and vetted the data analysis. MOA did a critical review of the manuscript. SOA took part in the manuscript preparation and material search. FRO/EEA administered the consent form and was involved in the data collection. All authors read and approved the final manuscript".

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Abbreviations:

Hysterosalpingography (HSG)
Thermoluminescent dosimeters (TLD)
Entrance surface dose (ESD)
Exit dose (ED)
Effective dose (E_{ff})
Dose area product (DAP)
Kerma-area product (KAP)
Optically stimulated luminescent dosimeter (OSLD)
Digital Radiography (DR)
Element correction factors (ECF)
Practical peak voltage (PPV)
Poly (methyl methacrylate) (PMMA)
Backscatter factor (BSF)
Focus to skin distance (FSD)
Body mass index (BMI)
Heath Protection Agency (HPA)
Film screen radiography (FSR)
Linear energy transfer (LET)
Computed radiography (CR)
National Council on Radiation Protection and Measurements (NCRP)
National Radiological Protection Board (NRPB)

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