

Cancer incidence risks to patients due to hysterosalpingography

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ABSTRACT

Cancer incidence estimates and dosimetry of 120 patients undergoing hysterosalpingography (HSG) without screening at five rural hospitals and with screening using image intensifier-TV at an urban hospital have been studied. Free in air kerma measurements were taken for patient dosimetry. Using PCXMC version 1.5, organ and effective doses to patients were estimated. Incidence of cancer of the ovary, colon, bladder and uterus due to radiation exposure were estimated using biological effects of ionising radiation committee VII excess relative risk models. The effective dose to patients was estimated to be 0.20 ± 0.03 mSv and 0.06 ± 0.01 mSv for procedures with and without screening, respectively. The average number of exposures for both procedures, 2.5, and screening time of 48.1 s were recorded. Screening time contributed majority of the patient doses due to HSG; therefore, it should be optimised as much as possible. Of all the cancers considered, the incidence of cancer of the bladder for patients undergoing HSG procedures is more probable.

Key words: Cancer, effective dose, fluoroscopy, radiation dose and risk estimates

Introduction

With the growing concern about radiation doses received by patients and cancer incidences over the years, there has been an emergent requirement for information on typical doses and the range of dose received during various radiographic and fluoroscopic examinations.^[1-4] A pregnant patient has a right to know the magnitude and type of potential radiation effects that might result from *in utero* exposure. Fetal doses below 100 mGy should not be considered a reason for terminating a pregnancy due to prenatal death, malformation or impairment of mental development of the fetus.^[5]

Hysterosalpingography (HSG) is a diagnostic radiology technique that enables the visualization of uterine and tubal pathologies using X-ray and a contrast material for the investigation of infertility for women.^[6,7] Although this examination cannot be considered to be of a high risk level according to the expected values of its imparted collective dose, the requirements for radiation protection optimisation are to be observed at an individual level because of the specificity of the patient-irradiated area and the high probability of pregnancy in the future. These facts stress the necessity of minimising the possibility of the incidence of cancer due to radiation exposure.^[6]

Radiogenic anomalies in the developing embryo of the woman undergoing the procedure and radiogenic fatal cancer induction to the woman under exposure are likely to be elevated if fluoroscopic or radiographic exposures are prolonged for any reason.^[8] Careful analysis of the working procedures and clinical protocols generally used in radiological practise, to avoid unnecessary exposures with no loss in diagnostic information, is required.^[9]

Risk of radiation-induced cancer is the main value that can evaluate the radiation harm on humans. Two models are employed for cancer risk projection for an exposed population. These are: (a) additive (absolute) risk model, which postulates that radiation will induce cancer

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independently of the spontaneous rate after a period of latency, variations in risk may occur due to sex and age at exposure and (b) the multiplicative (relative) risk model in which the excess (after latency) is given by a constant factor applied to the age-dependent incidence of natural cancers in a population. The relative risk model predicts increasing incidence of cancer with increasing age due to its proportionality to spontaneous risk. Relative risk also gives different risks of radiation-induced cancer in different populations. Studies done on A-bomb survivors and on uranium miners suggests that relative risk model gives a better fit to data, at least for some of most common cancer types.^[10,11] However, studies on exposed groups also suggests that the relative risk model applied over a lifetime could result in an overestimation of cancer risk, as the risk of cancer may start to decline many years after exposure.^[10]

Currently, two main HSG procedures are undertaken in the country, i.e. procedures using Image Intensifier (II)-TV for screening and those without screening. It is observed that the procedure without screening is commonly performed in the rural areas while the procedure with screening using II-TV is predominant in the urban areas.

This study assessed organ and effective dose using a Monte Carlo-based programme (PCXMC version 1.5)^[12] and estimated excess relative cancer risk using Biological Effects of Ionising Radiation (BEIR) committee VII phase 2 reports' empirical risk models for the two main HSG procedures employed in the country. The BEIR's relative risk model was used for this research because there is the inclusion of sex and all ages and the opportunity to assess risks for cancers of a large number of specific sites.^[10]

Organ doses calculated by PCXMC are given in proportion to the patient entrance air kerma at the point where the central axis of the X-ray beam enters the patient. The PCXMC uses computational hermaphrodite phantom defined by mathematical expressions to compute organ and effective doses to patients of different ages and sizes in freely adjustable X-ray projections and other examination conditions used in radiology.^[12] The program calculates the effective dose using recommendations of the International Commission on Radiological Protection (ICRP) publication 60^[13] with some modifications to the quantity from ICRP publication 73.^[4,12,14] The ICRP publication 60 has been superseded by ICRP publication 103, with modifications to the tissue weighting factors for the breast, which has been increased from 0.05 to 0.12, while that of the gonads has been reduced from 0.20 to 0.05. There has also been modification to the weighting factor for the "remainder tissue" and the inclusion of two more tissues, i.e. brain and salivary glands.^[15] PCXMC mimics the procedure at the hospital on a computer for easy dosimetry.

Materials and Methods

The study was carried out at five rural hospitals (Hospital B–F) performing HSG procedure without screening and an urban hospital (Hospital A) with screening using II-TV for the HSG procedure. For the study, 120 patients selected at random were used, with 100 patients undergoing HSG procedure without screening and the remaining 20 patients undergoing HSG procedure with screening using II-TV. All the procedures were performed by a radiologist with the assistance of radiographers using a film size of 24 cm x 30 cm for all cases. The radiographic images generated were passed by a radiologist.

Quality control

The entrance surface air kerma (ESAK) is highly dependent on the X-ray tube voltage and output. For this reason, the peak tube voltage (kVp) and output were checked for consistency using RMI model 240A (Gammex RMI Inc., Middleton, WI, USA) and RAD-CHECK PLUS (CE Inovision, Nuclear Associates Div. of Victoreen Inc., Carle Place, NY, USA) using the standard procedure as given in the Physics of Medical Imaging.^[16] The X-ray field and light beam alignment were checked by exposing a light-demarcated area on a radiographic film.

Entrance surface air kerma estimation

Free in air measurements with RAD-CHECK PLUS (CE Inovision, Nuclear Associates Div. of Victoreen, Inc.) placed at 100 cm from the X-ray tube were made, varying tube voltage (kV) and current–time product (mAs). The output ratio (mGy/mAs) is plotted against kV to obtain an ESAK curve.^[17] This procedure was repeated for all the six hospitals considered for the study.

From the curve, the output ratio (mGy/mAs) can be extrapolated with a known kV. The ESAK is estimated using equation 1 with a known focus to skin distance (FSD) and mAs per examination

$$ESAK_{(kVp,mAs)} = \left[\text{Output ratio (mGy / mAs)} \times \left(\frac{100}{FSD} \right)^2 \times mAs \right] \dots (1)$$

PCXMC dose estimation

Patient height and weight is inputted into the Monte Carlo code (PCXMC) developed by the Finish Radiation and Nuclear Safety Authority^[12] to acquire a mathematical phantom to represent the patient. The image size and focus-to-film distance are also inputted into the code to acquire the X-ray beam dimensions and FSD taking into account the obtained phantom. The X-ray beam direction and the part of the patient being diagnosed are indicated on the obtained phantom. With the obtained X-ray projection and patient orientation, the code simulates the information provided for dose estimation. The tube voltage, current–time product, X-ray filtration and ESAK are inputted into the simulated information for organ and effective dose calculation.

PCXMC uses ESAK or Entrance surface dose (ESD) without backscatter because it uses the Monte Carlo method in its dose estimation, i.e. there is a stochastic mathematical simulation of interactions between photons and matter.

Dose area product estimation

Dose Area Product (DAP) on the surface of the patient was estimated using the equation below with a known X-ray field area (A) at the focus-to-film distance (FFD), FSD and the estimated ESAK. In the absence of appropriate equipment, the mathematical relationship between DAP and ESD or ESAK may be used.^[18]

$$DAP = ESAK \times A_{FFD} \times \left(\frac{FSD}{FFD}\right)^2 \dots(2)$$

Cancer risk estimation

Empirical risk models developed by the Biological Effects of Ionizing Radiation (BEIR) Committee Report VII phase two were used to estimate excess relative cancer risk to patients due to radiation exposure. The empirical risk models used in this study are based on the Japanese Atomic bomb survivors. The excess relative risk (ERR) of cancer incidence was estimated using the equation below.

$$ERR = \beta_s D \exp(\gamma e) (a/60)^\eta \dots(3)$$

Where β_s is risk coefficient, which is sex (s) dependant, D is the organ dose, e is age at exposure (years), a is attained age (years), γ is per-decade increase in age (0–30 years) at exposure and η is the exponent of attained age at cancer incidence.^[10] β_s , γ and η are fitting parameters predetermined by BEIR. The cancer incidence to the ovary, uterus, colon and bladder were estimated.

Results and Discussion

In the study, women in the age range of 30–39 years were observed to undergo more HSG procedures as compared with women in the age range of 20–29 years and 40–49 years. This could be attributed to education; most of the women marry or think of making a family in their late 20s (20–29 years) and they start having offsprings in their 30s (30–39 years). The study also revealed that the HSG procedure reaches its peak with women in their 30s and declines in the 40s (40–49 years) due to medical complications. About 56.5% of the women involved in the study were between the age range of 30 and 39 years. Women in the age range of 40–49 years (36.4%) undergoing HSG in the hospitals considered are more than those in the age range of 20–29 years (9.1%). In a similar work conducted by Fife *et al.*,^[11] women in the age range of 20–29, 30–39 and 40–49 years accounted for 15%, 83% and 2%, respectively.^[11]

Mean X-ray field area on the surface of the patient was estimated to be 411.1 (383.7–441.4) cm² and 402.9 (374.2–434.5) cm² for HSG procedure with and without screening,

respectively. The mean FSD for HSG procedure with and without screening was recorded to be 76.0 (74.6–76.9) cm and 77.1 (75.2–78.4) cm, respectively. The FFD was fixed at 100 cm for both HSG procedures.

ESAK estimation curve for all the hospitals used for this study is presented in Figure 1. Hospital E has the highest radiation output at the same tube voltage for all the X-ray machines considered. There is no significant difference between the radiation output of Hospital A with screening and Hospital B, D and F without screening.

The ESAK, DAP and effective dose to patients undergoing HSG procedure with or without screening are illustrated in Table 1. ESAK, DAP and effective dose for HSG procedure with screening is approximately 3.7-, 3.5- and 3.3-times more than HSG procedure without screening, respectively. The effective dose value recorded for this study is expected to be low when calculated using the current ICRP publication 103^[15] because tissue weighting factor for the gonads has significantly been reduced and also because the gonads recorded significant doses for this study. From the study, the effective dose for HSG procedure with screening is 53% or more and 78% or more, more than that of chest posteroanterior and skull anteroposterior examinations, respectively, in Muhogora *et al.*^[3] Similarly, the effective dose for HSG procedure without screening is 17% or less, less than and 8% or more, more than that of chest posteroanterior and skull anteroposterior examinations, respectively, in Muhogora *et al.*^[3]

The screening time contributed 73%, 72% and 70% of the ESAK, DAP and effective dose of patients undergoing

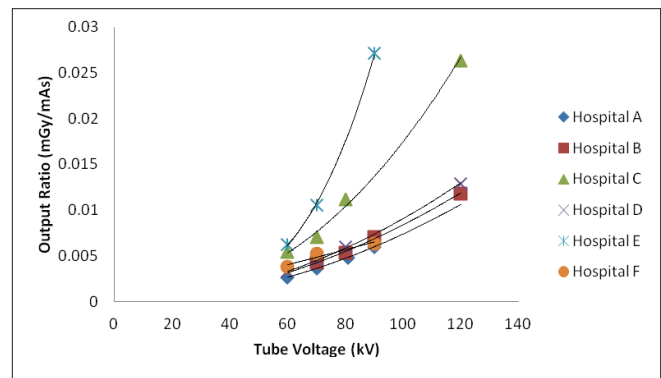


Figure 1: Entrance surface air kerma estimation curves for all the hospitals (Hospitals A–F)

Table 1: Mean ESAK, DAP and effective dose for HSG with and without screening

	Procedure with screening	Procedure without screening
ESAK (mGy)	1.33 ± 0.12	0.36 ± 0.10
DAP (Gycm ²)	0.53 ± 0.05	0.15 ± 0.04
Effective dose (mSv)	0.20 ± 0.03	0.06 ± 0.01

Values represented as mean ± standard deviation, ESAK: Entrance surface air kerma, DAP: Dose area product; HSG: Hysterosalpingography

the HSG procedure, respectively, compared with 70–90% in Abdullah *et al.*^[19] These values are more than 50% and hence the majority contributor to patient doses. Although radiation screening contributes majority of patient doses, it is very necessary, in the sense that the screening is done using II-TV, to obtain a good and precise radiographic image.

Screening and radiographic parameters for HSG procedure with or without screening are presented in Table 2. The radiographic tube voltages used for procedures with screening and without screening are not significantly different, and the number of exposures is the same. The mean radiographic current time product used for procedures with screening was more than procedures without screening by a factor of 1.4.

Table 3 represents the comparison of the findings of this study with other studies. It can be seen that the DAP increases with increasing screening time. Although DAP values from Gregan *et al.*^[20] and Abdullah *et al.*^[19] were obtained with a calibrated DAP meter, while that of this study was estimated from a mathematical relationship, comparison of the values are good for better optimisation in the hospitals.

Table 4 shows the mean organ doses to patients undergoing HSG procedure with or without screening. The urinary bladder received the highest amount of dose, followed by the uterus, ovaries and the lower large intestine in that order. It can be seen that the order of organ doses received in the descending order is the same for both HSG procedure with or without screening. The doses to organs in the body are in that order due to the position of these organs with respect to the part of the body exposed to the ionising radiation. The organ doses received by patients undergoing HSG procedure with

screening using II-TV are more than HSG procedure without screening by a factor of three or more. This is because of the high ESAK and DAP recorded for the HSG procedure with screening using II-TV as shown in Table 1.

Site-specific cancer incidence estimates due to HSG procedure with or without screening, 30 years after exposure, are presented in Table 5. It can be seen that HSG procedure with or without screening is more likely to cause cancer of the bladder than any of the cancers. The second and third most probable cancers in patients undergoing HSG procedure are those on the colon and ovary.

Conclusion

From the study, the high estimated ESAK for HSG procedure with screening resulted in high DAP, organ doses and effective dose when compared with HSG procedure without screening. The organs that recorded high doses were more probable to cancer incidence than the other organs considered for the study when compared. Screening time was found to be the major contributing factor to patient doses in the study and hence optimisation of screening time is encouraged. Of all the cancers considered, the incidence of cancer of the bladder for patients undergoing HSG procedures is more probable.

Table 2: Patient exposure details

	Procedure with screening	Procedures without screening
Screening peak tube voltage	69.7 (60–80)	-
Radiographic peak tube voltage	80.6 (77.0–85.0)	77.4 (50.0–90.0)
Screening current–time product (mAs)	86.2 (49–161)	-
Radiographic current–time product (mAs)	36.9 (32–40)	26.5 (20–40)
Fluoroscopy beam-on-time (s)	48.1 (22.0–70.0)	-
No. of exposures	2.5 (2.0–3.0)	2.5 (2.0–3.0)

Values represented as mean (range)

Table 3: Comparison of this study with other works

	This study	Gregan <i>et al.</i> ^[20]	Abdullah <i>et al.</i> ^[19]	Fife <i>et al.</i> ^[1]
No. of exposures	2.5 (2.0–3.0)	2 (2–4)	2	3.56 (2–6)
Screening time (s)	48.1 (22.0–70.0)	15 (5–45)	119 (44–285)	40.4 (11.0–91.0)
DAP (Gycm ²)	0.53 (0.35–0.78)	0.22	4.95 (2.20–13.0)	-

Values represented as mean (range)

Table 4: Mean organ doses to patients due to hysterosalpingography arrived at by PCXMC

Organs	Dose (mGy)	
	Procedure with II-TV	Procedure without II-TV
Ovaries	0.44 ± 0.08	0.15 ± 0.09
Lower large intestine	0.39 ± 0.03	0.10 ± 0.02
Urinary bladder	1.10 ± 0.02	0.29 ± 0.02
Uterus	0.65 ± 0.03	0.17 ± 0.01

Values represented as mean ± standard deviation

Table 5: Excess relative risk estimates for cancer incidence due to hysterosalpingography, 30 years after exposure

Site-specific cancers	Excess relative risk	
	Procedure with screening using II-TV (×10 ⁻³)	Procedure without screening (×10 ⁻³)
Ovary	0.18	0.06
Colon	0.17	0.04
Urinary bladder	1.82	0.49
Uterus	0.04	0.01

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