RADIATION DOSE AND RISK ASSESSMENT IN HYSTEROSALPINGOGRAPHY

by

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Hysterosalpingography is an important diagnostic method for the evaluation of the female reproductive tract involving the exposure of patients to ionizing radiation. The irradiation of ovaries is unavoidable and radiation exposure of the patient and the associated radiological risk for the foetus and born child during the period of growth should be considered, as well. The purpose of this work is to evaluate organ and patient doses and radiation risks during hysterosalpingography procedures performed in a dedicated gynecological hospital. The entrance surface air kerma was measured for a total of 31 patients during hysterosalpingography. Based on the results obtained, the radiogenic risk for hereditary effects and cancer induction was estimated. The patient dose levels are in the range of 3-15 mGy, with a median value of 10 mGy, in terms of entrance surface air kerma. Estimated median ovarian and uterus doses are 1.7 and 2.3 mGy, respectively. The risk for fatal cancer and hereditary effects is estimated to be $5.5\ 10^{-5}$ and $3.4\ 10^{-6}$, respectively. Although low compared to the natural incidence of genetic effects and cancer, it can be elevated in cases of prolonged or repeated procedures or procedures where the non-optimized protocol is used.

Key words: hysterosalpingography, dose, risk assessment

INTRODUCTION

Hysterosalpingography (HSG) is an important diagnostic method for the evaluation of the female reproductive tract that involves the exposure of patients to ionizing radiation. It is a relatively frequent radio-gynaecological procedure, generally used to assess the uterine cavity and patency of Fallopian tubes. The common indication for the use of HSG is primary and secondary infertility [1-4]. HSG is merely an initial step in gynecoradiological procedures. Depending on the findings, one may proceed with selective salpingography, tubal catheterization or with a similar therapeutic procedure [5]. In all radiological procedures in gynaecology, the irradiation of ovaries is unavoidable and one should, thus, consider both the radiation exposure of the patient and the radiological risks associated with it for the foetus and born child during the period of growth.

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Concerns over radiation doses received by patients and the associated radiation risks have become a major issue in recent years [6, 7]. The contribution of HSG to the collective dose is not significant [8, 9]; however, good radiation protection is of utmost importance at the individual level, as the said examination involves the irradiation of females of reproductive capacity and of the gonadal region of relatively young patients, with a possibility for repeated examinations. In that sense, any dose and/or risk information is welcome.

There are several studies on dose levels from HSG, mainly from screen-film radiological units. Assessed dose levels are commonly reported in terms of an easily measured entrance surface dose or dose-area product [10,11]. However, it is just as important to estimate organ and effective doses as quantities directly related to the radiological risk. In available literature, reported entrance surface air kerma (ESAK) for the HSG procedure is in the range of 9.7-30 mGy, while reported kerma-area product (KAP) values range from 4 to 7 Gycm^2 [1, 4, 8, 9, 12, 13]. A typical effective dose to the patient undergoing HSG as a part of infer-

tility work-up is 1.2 mSv to 3.1 mSv, with the ovarian dose in the range of 2.7-9.0 mGy. However, higher values of the effective dose (8 mSv) and corresponding ovarian dose (9-11 mG) were also reported [1, 13, 14]. Furthermore, the ovarian dose can be as high as 45 mGy [1], which certainly requires careful analysis and application of dose reduction strategies.

Frequently, radio-gynaecological procedures are performed outside the radiology department, by staff that is not fully skilled or trained in radiation protection. This requires special attention. Female patients referred to HSG are often anxious about radiation risks arising from the X-ray procedure. It is the responsibility of the operating staff to inform the patient of the radiogenic detriments on the future conceptus and radiogenic cancer induction on the exposed individual.

There are remarkable variations in radiological equipment used and clinical protocols applied in HSG among hospitals and, consequently, in the radiation dose and associated risks [1, 2 ,4, 12, 13]. As the post-HSG pregnancy rate is as high as 75% [4], it is important to assess levels of radiation doses and radiogenic hereditary risks for each particular hospital performing HSG.

The purpose of this work is to evaluate organ and patient doses and radiation risks during HSG procedures performed outside the radiology department, in a dedicated gynecological hospital.

MATERIALS AND METHODS

Our clinical protocol for the HSG procedure used in a dedicated gynaecological hospital consisted of several radiographies in anterior-posterior (AP) projections, following the *in utero* administration of a non-ionic radiological contrast. The protocol excluded any fluoroscopy, oblique or lateral projections. Fluoroscopy in itself is not of any diagnostic interest and is commonly used only to control the contrast low, while lateral and oblique projections may be substituted by echography in terms of relevant clinical information [1, 4, 13]. The examination protocol was designed in such a way as to minimize the patient radiation dose.

The survey was performed in June and July of 2010. All patients were examined using a three-phase, six pulse generator Superix 1000 (EI Niš, Serbia), with an over couch X-ray tube, anti-scattering grid (grid ratio 12:1) in-place and manual exposure control settings.

A solid state dosimeter, R-100 Barracuda (RTI Electronics, Sweden), calibrated in the traceable, Secondary Standard Dosimetry Laboratory at the Vinča Institute of Nuclear Sciences, was used for X-ray tube output measurements. The measured half-vale layer at 80 kVp was 2.5 mm Al. The X-ray tube output at 100 cm from the focal spot was 24, 35, 46, 57, 69, and 82 μGy/mAs for 50, 60, 70, 80, 90, and 100 kVp tube voltages, respectively.

Tube voltage, tube current, and exposure time were selected manually, by radiographer, to produce quality diagnostic images for the given patient size. The film size used for all images was 24 30 cm, with a fixed focus-to-film distance of 100 cm. The nominal speed class of film-screen combination was 400.

A total of 31 patients were monitored during the two month period. For each patient and projection, following personal data and technical parameters were collected: age, body weight, height, tube potential, tube current time product, focus-to-film distance, and film size used.

For each projection, ESAK was calculated using the following equation [10, 15-17]

$$ESAK \quad \frac{Y_D \; Q \; D^2}{[L \quad (d \quad b)]^2} \; BSF \qquad (1)$$

where Y_D is the X-ray tube output at distance D normalized by mAs (Gy/mAs), Q – the product of the tube current and exposure time, BSF – the backscatter factor [10], L – the focus-film distance and b and d – the film-table top distance and patient thickness, respectively. To calculate ESAK, X-ray tube output Y_D was measured at a distance of 1 m for the X-ray tube potential in the range of 50-100 kV, in 10 kV steps, as described before. Patient thickness was deduced from the recorded patient weight and height. For each projection, ESAK was calculated using real examination data, according to eq. (1). The total dose for each patient was calculated as a sum of contributions from multiple projections.

Using the relationship between KAP and ESAK for a given filed size [18]

$$KAP \quad \frac{ESAK}{BSF} \; A(L) \; \frac{L \quad (d \quad b)}{L}^{\;2} \qquad (2)$$

where A is a filed size, KAP was assessed for each projection and each patient. KAP is a good indication of the risk for stochastic effects, as it is directly related to the effective dose. A conversion factor of 0.29 mSv/Gycm^2 was used to calculate the effective dose from assessed KAP values [19].

To allow the estimation of organ doses for ovaries and uterus, United Kingdom National Radiological Protection Board's conversion factors have been used [18]. ESAK and KAP as input parameters have allowed organ dose assessment for each patient and actual radiation quality. In this way, the calculated organ dose is slightly overestimated, due to the lack of specific organ dose conversion factors for HSG. Instead, a pelvic AP projection was used [13].

The radiation risk following HSG was estimated using available risk coefficients obtained from the International Commission for Radiological Protection Report 103 [20]. The risk of cancer was calculated us-

ing detriment-adjusted nominal risk coefficients for stochastic effects after exposure to radiation at a low dose rate. For the whole population, the given risk coefficient is 5.5 10^{-2} Sv^{-1}. Although significantly lower (27 times) than the risk of cancer development, the risk of genetic effects in future generations was obtained by multiplying the mean dose to ovaries with the risk factor of 0.2 10^{-2} Sv^{-1} [20].

RESULTS

In total, 31 patients were studied. The age of patients covered by the survey ranged from 19-43 years, with mean and median values of 31. The average body mass of these patients was 68 kg, with an associated range of 45-85 kg. Typical exposure parameters and dosimetry data are presented in tab. 1. All HSG examinations in this study were simple, without any need for further therapeutic procedures.

Table 1. Typical exposure parameters and dose values from HSG examination of 31 patients

Parameter	Mean	Median	Range
Number of exposures	2.9	/	2-3
Tube voltage [kVp]	73	74	60-90
Tube current time product [mAs]	32±6	32	20-40
ESAK [mGy]	10±3	10	3-15
KAP [$Gycm^2$]	3.2 0.92	3.2	1.1-4.5
Ovarian dose [mGy]	1.6	1.7	0.25-2.8
Uterus dose [mGy]	2.2±0.82	2.3	0.38-3.8

According to data presented in tab. 1, it is estimated that doses to ovaries and uterus present 16% and 22% of ESAK, respectively. A mean effective dose of 1 mSv per patient from the HSG procedure is estimated using the suitable convection coefficient of 0.29 mSv/$Gycm^2$. The risk of radiation induced hereditary effects was determined by multiplying the ovarian dose with the risk factor of 0.2 10^{-2} Sv^{-1}. The said risk for deleterious effects on the future foetus from a HSG procedure performed on the mother was found to be 3.4 10^{-6}. Using a risk factor of 5.5 10^{-2} Sv^{-1}, the estimated risk of cancer induction in the exposed individual was estimated to be 55 10^{-6}.

DISCUSSION

Results obtained in this study are similar or lower compared with results published in corresponding studies, as presented in tab. 2. This can be associated with the exclusion of fluoroscopy from the examination protocol and a typically smaller number of radiographs obtained in our study. If fluoroscopy is a part of the examination protocol, the contribution to the total dose from fluoroscopy is, typically, 25% [1, 13]. Therefore, a considerable portion of the dose arising from radiography indicates that there is scope for dose reduction in that part of the examination protocol.

Table 2. Comparison of patient dose values for the HSG procedure obtained in different studies

	Number of patients	Number of radiographs	ESAK [mGy]	KAP [$Gycm^2$]	Ovarian dose [mGy]	Uterus dose [mGy]
This study	31	2.9	10	3.2	1.7	2.3
Fernandez *et al*. [13]	41	7	/	7.13	4.6	/
Fife *et al*. [12]	40	3.6	15.9	/	2.8	/
Gregan *et al.* [1]	45	2	13.1	/	3.1	/
Sulieman *et al*. [2]	37	0.2	3.6	/	0.91	1.28
Calcchia *et al*. [21]	37	6.5	25	/	4.66	6.35
Perisinakis *et al*. [4]	78	3.2	9.7	/	2.7	/

The screen-film radiography unit used in our study is over 20-year-old and is not equipped with dose-reduction tools available in modern technologies. The main factors contributing to the patient dose in HSG are technical exposure parameters, filtration, type of generator, collimation, focus-to-skin distance and individual pathology. Although the patient dose depends on many factors, the single largest contributory factor is patient size, as other parameters were kept constant in this survey. Possible dose reduction strategies in this case would include the use of higher tube voltages, lower tuber current time product values, and increased beam filtration.

Increasing tube voltage is an efficient method for dose reduction in HSG, as ovarian dose decreases by about 50% when the tube voltage is increased from 70 kV to 120 kV [3]. Furthermore, the use of additional filtration could lead to a dose reduction of more than 80%, without loss of HSG image quality in computed radiography systems [22].

It is likely that the use of high frequency generators, automatic exposure control and digital image receptors would contribute significantly to dose reduction [1, 2]. Published results on patient doses, in terms of ESAK, from digital X-ray units are in the range of 2.3-3.9 mGy, which is considerably less than the dose values from analogous X-ray units used for HSG examination [1, 2]. Furthermore, the use of digital fluoroscopy would enable the production of hard copy images from stored digital images (image capture) without a need for further patient exposure.

There is evidence of an almost six times dose reduction as a result of transition from screen-film to digital imaging equipment. In a comparative HSG dosimetric study performed by conventional screen-film under couch X-ray units and digital C-arm radiological fluoroscopy units, reported entrance surface doses were 15 mGy and 2.5 mGy for screen-film

and digital units, respectively. The corresponding ovarian doses were 3.5 mGy and 0.5 mGy [1].

HSG involves direct irradiation of the pelvic region, with organs at higher risk being the ovaries and the uterus. The mean estimated organ doses from this study are 1.6 mGy and 2.2 mGy for ovaries and uterus, respectively. The ovarian dose in terms of an X-ray equivalent dose is a good indicator of the stochastic risk arising form the HSG procedure. In this study, ovarian doses present 16% of total ESAK, which is similar or slightly lower than values ranging from 15-30% obtained in similar studies [1-3]. A possible explanation may be found in the fact that the soft beam quality used in this case contributes to higher surface doses and lower organ and effective doses.

An efficient method for organ dose reduction is the use of the posterior-anterior projection (PA) instead of the AP projection. In PA projection, organs of interest are located at a greater depth in the body which provides a dose reduction of about 60-75% for ovaries and of 30-43% for the uterus for tube voltages in the range of 70-120 kVp [3].

Radiation risk estimation for fatal cancer and hereditary effects is estimated to be low ($3.4\ 10^{-6}$). Furthermore, the radiation dose to the uterus could be used for the assessment of foetal doses in cases of unconfirmed pregnancies. The risk of hereditary effects from ionising radiation has been substantially revised in the past decades and is, at present, estimated to be around five times lower then previously thought. The risk of inducing hereditary effects in the first two generations following *in utero* irradiation (1 in 200000 per mGy) is over ten times lower than the risk of inducing childhood cancer (1 in 13000 per mGy) and is also very small when compared to the natural risk of congenital defects (1-6%). Also, the estimated risk of cancer induction is several orders of magnitude lower than the natural cancer incidence of 1:3 [23, 24].

CONCLUSION

Our study presents the results of the first dose and risk assessment for HSG in Serbia. In terms of ESAK, estimated patient dose levels are in the range of 3-15 mGy, with a median value of 10 mGy. Estimated median ovarian and uterus doses are 1.7 mGy and 2.3 mGy, respectively. The estimated risk of fatal cancer and hereditary effects is low compared to the natural incidence of genetic effects and cancer. However, it can be elevated in cases of prolonged or repeated procedures or use of non-optimized protocols.

So as to enable the establishment of national diagnostic reference levels as a part of the optimization procedure, it is necessary to expand this survey and include more hospitals performing HSG procedures. The minimization of the dose and associated radiological risks during HSG is possible by applying all available radiation protection tools that are in line with acceptable image quality of desired diagnostic information.

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ПРОЦЕНА ДОЗЕ И РАДИЈАЦИОНОГ РИЗИКА У ХИСТЕРОСАЛПИНГОГРАФИЈИ

Хистеросалпингографија (ХСГ) је једна од значајнијих дијагностичких процедура репродуктивног тракта пацијената женског пола која укључује излагање јонизујућем зрачењу. Доза за јајнике је неизбежан део овог дијагностичког поступка, те доза за изложеног појединца и радијациони ризик за будуће генерације захтевају пажљиву анализу. Циљ овог рада је процена дозе за органе и претећег радијационог ризика током ХСГ процедура реализованих у специјализованој гинеколошкој болници. Керма у ваздуху на површини коже пацијента измерена је за укупно 31 пацијента током ХСГ. На основу измерених вредности процењен је радијациони ризик за хередитарне ефекте и настанак карцинома. Процењене дозе за пацијенте биле су у опсегу од 3–15 mGy, са медијаном од 10 mGy. Процењене типичне вредности дозе за јајнике и утерус биле су 1.7 и 2.3 mGy, респективно, док одговарајући ризик за фатални карцином и хередитарне ефекте износе $5.5\ 10^{-5}$ и $3.4\ 10^{-6}$, респективно. Иако је процењен ризик мали у поређењу са природном инциденцом за наследне ефекте и карцином, он може бити значајно увећан у случају процедура продуженог трајања, поновљених процедура на истом пацијенту и уколико се примењују неоптимизовани протоколи прегледа.

Кључне речи: хистеросалпингографија, доза, радијациони ризик