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Evaluation of the Influence of Additional Beam Filtration on Image Quality and Patient Dose in X-ray Fluoroscopy Procedures

Justin E Ngaile[1, 2*], Peter K Msaki[2], Ramadhani R Kazema[3], Jerome M Mwimanzi[1] and Mechris Mango[4]

[1]*Radiation Control Directorate, Tanzania Atomic Energy Commission, P.O. Box 743, Arusha, Tanzania*
[2]*Department of Physics, University of Dar es Salaam, P.O. Box 35063, Dar es Salaam, Tanzania*
[3]*Department of Radiology, Muhimbili University of Health and Allied Sciences, P.O. Box 65001, Dar es Salaam, Tanzania*
[4]*Department of Radiology, Muhimbili Orthopedic Institute, P.O. Box 65474, Dar es Salaam*
[*]*Corresponding Author e-mail address: jngaile@gmail.com*

Abstract

The aim of the study was to evaluate the influence of additional filtration on radiation dose and image quality for patients during hysterosalpingography (HSG) and retrograde urethrography (RUG) procedures. The influence of filtering on image quality for each phantom thickness was made using a combination of different filter thicknesses. Entrance surface air kerma (ESAK) rates to Perspex phantom were measured using a solid state detector for various added combination of filter materials. Fluoroscopic image contrast was assessed using a Leeds TOR-18FG test object with a range of filter materials and phantom thicknesses. Phantom studies demonstrated that the use of additional filter materials of up to 0.35 mm thickness of copper could be used without significant effect on the image quality. ESAK values were determined for 16, 20, 24 and 28 cm phantom. Phantom ESAK reduced by 63%, 63%, 64% and 65% for 16, 20, 24 and 28 cm, respectively, when using 0.35 mm Cu + 1 mmAl, without degrading image contrast. Three independent radiologists perceived no change in clinical image quality with added filtration. On adding 0.35 mm Cu and 1 mm Al, the KAP per examination for the HSG was reduced by 71%, while for the RUG was reduced by 75%.

Key words: Additional filtration, image quality, patient dose, X-ray fluoroscopy procedures

Introduction

Contrast investigations of hysterosalpingography (HSG) and retrograde urethrography (RUG) fluoroscopy procedures studied under fluoroscopy guidance remain the dominant diagnostic tools for the diagnostic evaluations of infertility in females and urethral strictures in males, respectively, particularly in developing countries owing to the scarcity and high costs of services of alternative diagnostic technologies (Merkle et al. 1996, Efstathopoulos et al. 2013, Maciejewski and Rourke 2015). Notwithstanding the promising clinical results, the conventional HSG and RUG examinations continued to suffer from inevitable radiation doses to patients in consequence of the use of a combination of fluoroscopy and a large number of radiographic images from different projections (Calicchia et al. 1998, Kramer et al. 2006). As a result of the relative high radiation dose delivered to patients from the HSG and RUG procedures, there have been great concerns of the possible undesired health effects such as cancer induction following direct X-ray irradiation of pelvic region, in which some of most radiosensitive organs including ovaries, uterus and urinary bladder for the HSG and testes and urinary bladder for the RUG, are in the primary beam (Yoder and Papanicolaou 1992, Merkle et al. 1996, Philips et al. 2010, Maciejewski and Rourke 2015). Of particular concern are the young male patients undergoing RUG and the young female patients undergoing HSG procedures, which in addition to radiation induced cancer they are susceptible to potential risk of genetic hereditary disorders due to changes in the sperms (in males) and in oocytes (in females) (Merkle et al. 1996, ICRP 2007, Plećaš et al. 2010, Efstathopolous et al. 2013).

Despite the fact that radiation doses received by the patients with single examination scarcely reach the stated thresholds, optimization strategies and procedures to minimize such doses are nevertheless required for a given procedure in order to reduce the probability of the associated radiological risks (ICRP 2007). In an effort to minimize radiation burdens to patients from contrast-based X-ray fluoroscopy procedures without impairing image quality, a wide range of operator-based dose reduction strategies have been established (Martin et al. 1998). These include reduction in fluoroscopy time, tube current, number of radiographs, additional beam filtration, and selective use of the anti-scatter grid (Martin et al. 1998, Martin 2004). A number of scientific publications recommended the use of additional beam filtration in X-ray fluoroscopy (Geleijns et al. 1998, Martin 2004, Morrell et al. 2004). The employment of additional filter material (i.e., aluminium (Al), copper (Cu), and tin (Sn)) for X-ray fluoroscopy is motivated primarily by its ability to absorb soft and lower-energy (photons) X-rays having no or small contribution to the image formations (Martin 2004, 2007). However, the literatures demonstrate concern that additional beam filtration must be weighed against the increased tube loading and possible degradation of image quality through a need for prolonged exposure time and a possible reduction in image contrast (Morrell et al. 2004, Martin 2007). Few studies have demonstrated that Cu filters of up to 0.3 mm in thickness could lower the dose to patients in barium based contrast X-ray fluoroscopy examinations up to 50% without compromising the image quality (Morrellet al. 2004, Livingstone et al. 2007, Berner et al. 2010). Thus, there is a need to investigate if further dose reduction could be achieved using a wider range or combinations of filter materials. The aim of this study was to evaluate the effect of the modulation of radiation spectrum with the use of alternative X-ray filters on patient dose and image quality in contrast based X-ray fluoroscopy procedures of the hysterosalpingography and retrograde urethrography**.**

Materials and Methods

Description of data sources

In order to attain the purpose of this study, both phantom and patient studies were performed. The data used in this study were collected between April 2015 to July 2016 from the Muhimbili Orthopedic Institute (MOI), Dar es Salaam, Tanzania. The data desired for phantom studies were obtained using a rectangular chest Perspex slab phantom of 1 cm x 30 cm x 30 cm. The data needed for patient studies were obtained from 125 patients (61 males, 64 females) who underwent contrast based X-ray fluoroscopy procedures of the HSG and RUG. Both phantom and patient examinations were carried out using a Philips fluoroscopic system (Philips, Duo Diagnost, Eindhoven, The Netherlands) consisting of under coach image intensifier with three selectable input field diameters of 38, 31 and 23 cm. The focus-to-image distance was 110 cm and the equipment used a maximum tube voltage of 150 kV. The total X-ray beam filtration provided by X-ray tube and its housing was 2.85 mm Al, whereas the anode angle was 13°. The X-ray tube light-beam diaphragm was fitted with a KAP meter (PTW DIAMENTOR E2, type 11033-03515, PTW-Freiburg, Freiburg, Germany), which provided a further 0.2 mm Al equivalent filtration.

To ensure proper functioning of the X-ray fluoroscopy unit in compliance with the existing standards (IPEM 2005, IAEA 2007), dosimetric and image quality assessments were performed during the study. The performance tests such as kV reproducibility, kV accuracy, beam quality for each X-ray tube and the function of the ABC were performed using Unfors Xi multimeter (Unfors Xi, type No. 8201031-H Xi, Ser. No. 181017, Unfors Inc., Billdal, Sweden) with solid state detector (Unfors Xi, type No. 8202031-H Xi, Ser. No. 181017) that has calibration traceable to Swedish National Testing and Research Institute. From calibration report, uncertainty of the detector in dose measurements was estimated to be <2.7%, whereas the energy dependence for tube potential was estimated to be <1.0%. The image quality tests including low and high contrast resolution were carried out using a Leeds test object TOR 18FG (Leeds Test Objects Limited, Boroughbridge, UK) (Cowen et al. 1992). Prior to the study, ethical clearance with Ref. No. NIMR/HQ/R.8a/Vol. IX/1672 was obtained from the National Institute for Medical Research (NIMR) and from the respective hospital.

Phantom studies

The purpose of the phantom studies was to determine the appropriate thickness of filter material prior to clinical studies. In order to facilitate this, several copper filters (model 116, Gammed Inc., Middleton, USA) with dimensions of 10 cm x10 cm with thicknesses ranging from 0.10 to 0.80 mm in steps of 0.05 mm were prepared and thereafter fitted on the light beam diaphragm aperture. In each copper filter, 1 mm Al (model 115A, Gamme Inc., Middleton, USA) with dimensions of 10 cm x 10 cm was included on patient side of a copper filter in order to absorb secondary radiation generated from the copper filter (Martin et al. 1999, Gilson et al. 2010). The thicknesses of filters used for the phantom studies are given in Table 1. Appropriate phantom thickness was determined from previous patient thickness records for 127 patients that underwent the HSG and RUG fluoroscopy procedures where the patient transverse diameter was measured using slide caliper. The distribution of patient transverse diameter is given in Figure 1. A phantom thickness of 20 cm was selected to represent the median diameter, while 16, 24 and 28 cm representing thin, large and very large adult patients, respectively. Perspex slabs of dimensions of 30 cm x 30 cm x 1 cm were employed to build phantom thicknesses of 16, 20, 24 and 28 cm. The ratio between polymethyl-methylacrylate (PMMA) phantom and the patient body thickness can be considered to be approximately 1.5 (Rassow et al. 2000).

Table 1: Aluminium (Al) and copper (Cu) filter thicknesses employed for phantom studies

Setting	Filtration
0T	Equipment standard filtration without additional filtration
1T	Equipment standard filtration + 0.10 mm Cu + 1 mm Al
2T	Equipment standard filtration + 0.20 mm Cu + 1 mm Al
3T	Equipment standard filtration + 0.25 mm Cu + 1 mm Al
4T	Equipment standard filtration + 0.30 mm Cu + 1 mm Al
5T	Equipment standard filtration + 0.35 mm Cu + 1 mm Al
6T	Equipment standard filtration + 0.40 mm Cu + 1 mm Al
7T	Equipment standard filtration + 0.45 mm Cu + 1 mm Al
8T	Equipment standard filtration + 0.50 mm Cu + 1 mm Al
9T	Equipment standard filtration + 0.55 mm Cu + 1 mm Al
10T	Equipment standard filtration + 0.60 mm Cu + 1 mm Al
11T	Equipment standard filtration + 0.65 mm Cu + 1 mm Al
12T	Equipment standard filtration + 0.70 mm Cu + 1 mm Al
13T	Equipment standard filtration + 0.75 mm Cu + 1 mm Al
14T	Equipment standard filtration + 0.80 mm Cu + 1 mm Al

The influence of each additional filtration on entrance surface air kerma (ESAK) rates and image intensifier input kerma rates were measured by using a solid state detector Unfors Xi (model 8201013-C Xi) with a measurement probe (model 8202031-H Xi) positioned on top of the Perspex with the distance from the focal spot to the Perspex exit surface set to 100 cm, as shown in Figure 2. The ESAK and ESAK rates values displayed by the Unfors Xi multimeter during fluoroscopic screening and image acquisition were collected for each exposure. Likewise, the technical parameters (i.e., kV, mA, mAs) for fluoroscopy screening and radiographic imaging, displayed in the console were manually recorded for every exposure.

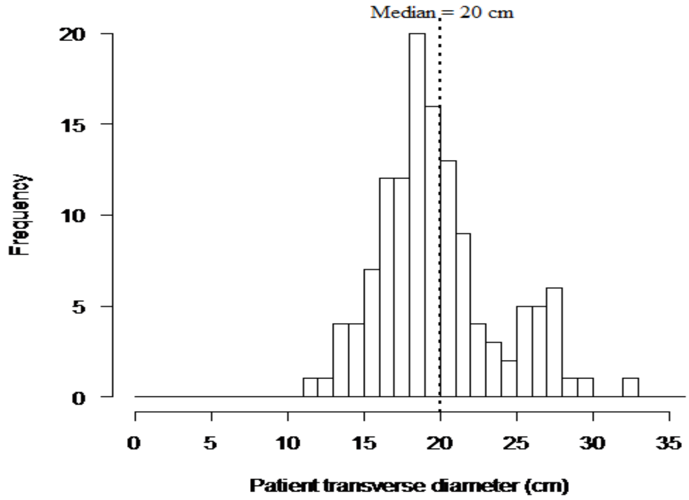

Figure 1: Distribution of patient transverse diameter (cm) for adult patient registered for the HSG and RUG fluoroscopy procedures.

(a) (b)

Figure 2: The experimental setup to measure (a) entrance surface air kerma and (b) image intensifier input kerma rates using Perspex slab phantom.

In order to examine the high contrast spatial resolution and low contrast resolution, the Leeds TOR -18FG test object (Leeds Test Objects Limited, Boroughbridge, UK), was positioned at the isocentre and at the middle of the Perspex thickness during all measurements involving image quality tests, thus providing the best geometry to simulate real clinical conditions. The high contrast spatial resolution was assessed by identification of the group of line pairs (Figure 3A) up to the point where the lines of the test object were distinct. The low contrast resolution was examined by the identification of the different circles (Figure 3A and 3B) that could be visualized in relation to the density of the plate containing them.

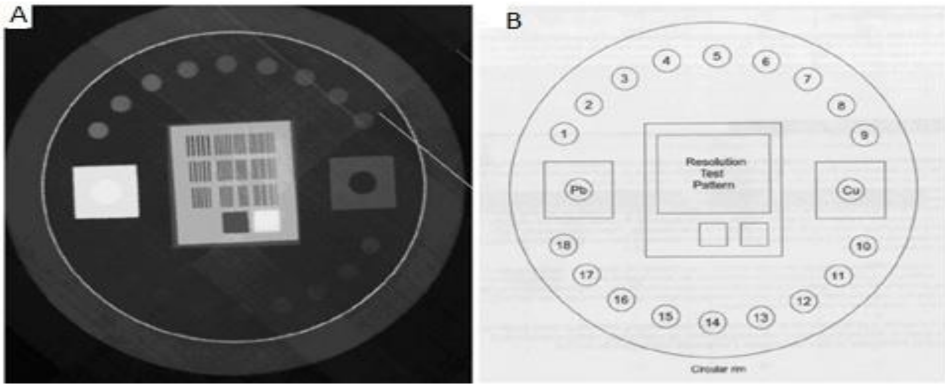

Figure 3: The Leeds TOR-18FG test phantom contrast images using (A) 65 kV X-rays showing group of line pairs and circles 1-13, and (B) 18 different circles for low contrast resolution.

Patient studies

Based on the results from the phantom studies, six different parameters settings (i.e., 0T, 1T, 2T, 3T, 4T and 5T) suitable for inclusion in the patient study were identified. A total of 125 patients were randomly recruited into study of air kerma area product (KAP) to patients undergoing the HSG and RUG fluoroscopy procedures. Out of 125 patients, 61 female patients were for the HSG procedures and 64 male patients were for the RUG procedures. The additional filtration was introduced into the clinical practice for copper filters of up to 0.35 mm in thickness. Since the additional filter material blocked the light beam used for setting X-ray field alignment and collimation, the Cu and Al filter was then taped to a thin sheet of Perspex, in order that it would slide in and out of the beam as required. The 61 patients recruited for the HSG were divided into six groups. In the first group of 11 patients, determination of dose to patients from HSG procedures was done without additional filtration. In the second, third, fourth, fifth and sixth groups of 10 patients each, measurements of doses were done with additional filtration of 1T, 2T, 3T, 4T and 5T, respectively. On the other hand, the 64 patients recruited for the RUG procedures were divided into six groups. In the first group of 14 patients, determination of dose to patients from RUG fluoroscopy procedures were done without additional filtration, while the second, third, fourth, fifth and sixth groups of 10 patients each, determination of patient doses were done with additional filtration of 1T, 2T, 3T, 4T and 5T, respectively.

Image quality evaluation

The quality of the patient images during HSG and RUG fluoroscopy procedures was subjectively evaluated by three experienced radiologists for perceptible differences in image quality in the HSG and RUG procedures using image quality criteria recommended by the European guidelines on quality criteria for diagnostic radiographic images (EC) (EC 1996). The five image quality criteria for the HSG were: (a) production of the uterus opacification or uterine outline; (b) density of the intrauterine cavity; (c) reproduction of the fallopian tubes; (d) visually sharp reproduction of fimbrialrugae; and (e) visualization of sharp reproduction of the intraperitoneal spillage. The three image quality criteria for the RUG procedures were: (a) production of the whole urinary bladder area to the base of urethra; (b) visualization of the urinary bladder mucosa; and (c) opacification of anterior urethra.

In each set of radiographic images, the radiologists were required to evaluate the level of fulfilment against each image quality criteria using score scale of 0 to 4, where "0" corresponds to no fulfilment, "1"corresponds to poorly fulfilled, "2" corresponds to fairly fulfilled, "3" corresponds to adequately fulfilled, and "4" corresponds to completely fulfilled. The observers were also required to comment on the reason/s for any scores below 3 and whether the radiographic images were of diagnostic quality. The mean image quality scores for images without (0T) and with 1T, 2T, 3T, 4T and 5T additional filter thicknesses were determined. The radiologists were then asked to comment on the causes for score below 3, and to classify each examination as "diagnostic or non-diagnostic. The mean image quality score per images without and with 1T, 2T, 3T, 4T and 5T additional filtration were then determined.

Statistical analysis

Statistical analyses and graphing were performed using Microsoft Excel 2007. The mean, median, standard deviation (SD), range and third quartile of the distribution of patient demographic parameters, technical parameters, dosimetric parameters (i.e., KAP) recorded and measured during the procedures were determined at each examination. A confidence level of 95% was used in all statistical calculations. Hence, a p-value < 0.05 was considered as significant.

Results and Discussions

Phantom studies

The ESAK to the phantom with and without different thicknesses of filter materials was determined as described earlier using solid state detector Unfors Xi and the results are shown in Table 2. The results indicate that for 38 cm field size of the phantom, the addition filtration of up to 0.35 mm Cu (+ 1 mm Al) enabled reduction of doses by 42.0%, 57.3%, 60.7%, 65.1% and 66.6% for 1T, 2T, 3T, 4T and 5T, respectively, of additional copper filtration relative to dose from non-filtered phantom. The difference between the mean ESAK value received by the phantom with 1T of additional filtration and that received by the phantom without additional filtration was not statistically significant (p = 0.0781), while for 2T, 3T, 4T and 5T, the differences were statistically significant (i.e., p = 0.0151, p = 0.006, p = 0.002 and p = 0.000, respectively). Similar observations were observed for other phantoms, where the ESAK rates were reduced for about 63%, 64%, and 65% for 16, 24 and 28 cm phantom, respectively, when 0.35 cm Cu and 1 mm Al were used.

Figure 4 shows the fluoroscopic entrance surface dose rates to a 20 cm Perspex phantom with varying amounts of copper filtration, at the three field sizes used in clinical practices. The first 0.1 mm copper lowered the ESAK rates by 42%, 41.6% and 32.3% for 38, 31 and 23 cm FS, respectively, and each additional 0.05 mm Cu gave a sequentially small dose reduction. The observed small dose reduction for each additional 0.05 mm Cu was partly attributed to the beam hardening effects of the copper itself, since an X-ray beam that has already had many of its low energy photons removed is less strongly affected by an additional layer of filter materials. The small decrease of dose was also attributed to the increase in X-ray tube potential as more filtration was added, since this again results in a more penetrating X-ray beam.

Table 2: Mean fluoroscopy entrance surface air kerma (mGy) for 20 cm Perspex phantom

Filter thickness	38 cm field size		31 cm field size		23 cm field size	
	Mean (µGy/s)	Reduction in (%)	Mean (µGy/s)	Reduction in dose (%)	Mean (µGy/s)	Reduction in dose (%)
0T	156.4		254.0		329.1	
1T	90.8	42.0	148.4	41.6	222.9	32.3
2T	66.8	57.3	114.0	55.1	178.5	45.8
3T	61.5	60.7	105.3	59.0	162.1	50.7
4T	54.6	65.1	94.0	63.0	150.7	54.2
5T	52.2	66.6	91.3	64.1	141.6	57.0
6T	50.8	67.5	90.9	64.2	127.7	61.2
7T	50.1	68.0	89.8	64.6	110.1	66.5
8T	49.7	68.2	88.0	65.4	96.6	70.6

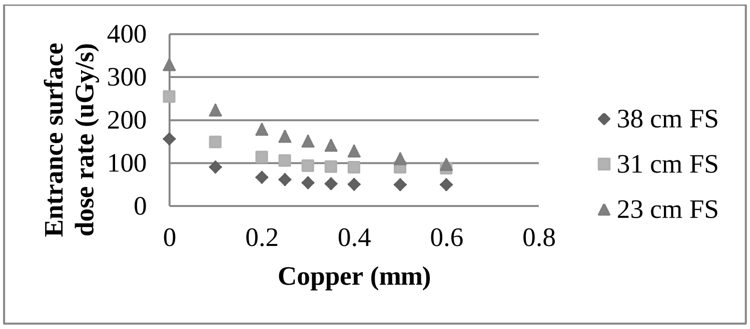

Figure 4: Entrance surface air kerma dose rate for fluoroscopic exposure of a 20 cm Perspex phantom for 38, 31, and 23 cm field size.

Figure 5 reveals the automatic fluoroscopic tube voltage selection for fluoroscopic exposure mode with 20 cm Perspex slab phantom and varying thickness of the copper filtration, at the three field sizes employed in clinical practice. For the field size of 38 cm and 31 cm, the tube potential steadily increased with increasing copper filtration, but did not reach its maximum values of 110 kV, while for 23 cm field size, the kV reaches its maximum values of 110 kV when 0.3 mm copper filter was introduced. Though for the 38 and 31 cm field sizes fluoroscopic kVs did not attain their maximum kV of 110 for a 20 cm Perspex phantom, the saturation of both tube potentials and current was observed for thicker phantoms of 24 and 28 cm. This resulted in a reduction of input kerma at the image intensifier, since the unit could no longer compensate for the increased beam attenuation. This in turn led to a decrease in the signal to noise ratio and hence degradation of contrast. This proved to be limiting factor in determining the optimum amount of copper filtration. The 0.35 mm copper filter was selected as it seemed to provide the most appropriate balance between the benefits of radiation dose reduction to patients and degradation of image quality. In view of the fact that patients are not cylindrical, projections involving long X-ray path through the patient such as lateral view would be most readily affected by saturation. However, for the HSG and RUG fluoroscopy procedures, majority of the clinical exposures were anteroposterior (AP), AP oblique or right anterior oblique (RAO) projections for which the ray path was shorter than the patient equivalent diameter.

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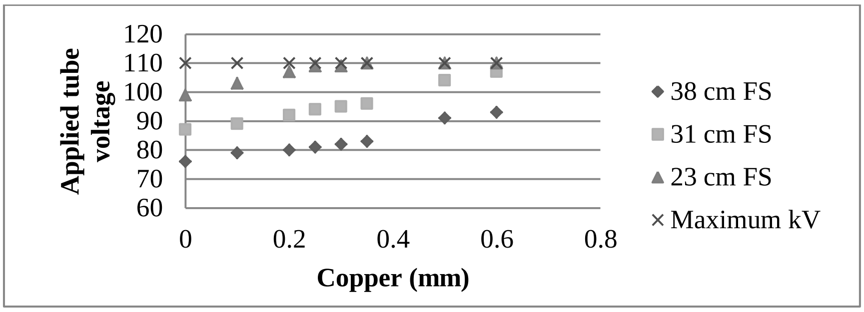

Figure 5: Automatic kV selection for fluoroscopic exposure of 20 cm Perspex phantom for 38, 31 and 23 cm field size.

The image obtained with 0.35 mm Cu filter appeared almost with no artifacts and were visibly sharp. Deterioration in the image quality was observed when the filter was increased further to 6T (0.40 mm Cu + 1 mm Al) and 7T (0.45 mm Cu + 1 mm Al). This degradation in image quality was observed due to reduced photon flux of the resulting X-ray beam, causing high statistical noise. The spatial resolution for 20 cm phantom with 38 cm field size was found to be 1.4, 1.4, 1.4, 1.4, 1.25 and 1.25 Lp/mm, for 0T, 1T, 2T, 3T, 4T and 5T filters, respectively. For 31 cm field size, the spatial resolution was found to be 2.0, 2.0, 2.0, 2.0 1.80 and 1.80 Lp/mm for 0T, 1T, 2T, 3T, 4T and 5T, respectively, which were above the recommended limit of > 1.0 Lp/mm (Cowen et al. 1992, IPEM 2005). The low contrast resolution was poor for all filters including the one without filter due to the fact that all were above the tolerance limit of 3.3% (Cowen et al. 1992, IPEM 2005).

Patient studies

The KAPs to the HSG and RUGfluoroscopy procedures with and without additional filtration were determined as described earlier using typical exposure parameters employed by the hospital. The results of the KAP measurements are given in Table 3. The results indicate that the additional beam filtration enabled reduction of the KAPs to the HSG by 23%, 41%, 55%, 62% and 71% for 1T, 2T, 3T, 4T and 5T, respectively. These differences in mean values of KAPs to the HSG between non-filtered (without) and filtered with additional filtration of 1T was not statistically significant ($p = 0.0624$), while for 2T, 3T, 4T and 5T, the differences were statistically significant (i.e., $p = 0.006$; $p = 0.002$; $p = 0.0005$ and $p = 0.000$, respectively). On the other hand, the results revealed that the additional beam filtration enabled reduction of the KAPs to the RUG by 22%, 53%, 61%, 67%, and 75% for 1T, 2T, 3T, 4T and 5T, respectively. These differences in mean values of KAPs to the RUG between non-filtered and filtered with 1T were not statistically significant ($p = 0.1918$), while were statistically significant ($p = 0.0310$; $p = 0.0058$; $p = 0.000184$; $p = 0.000913$) with 2T, 3T, 4T and 5T, respectively. The quality of the patients' images for the contrast-based X-ray fluoroscopy procedures of the HSG and RUG were subjectively evaluated by three experienced radiologists for perceptible differences in image quality of the HSG and RUG procedures with filtration of 1T, 2T, 3T, 4T and 5T compared with non- filtered HSG and RUG procedures as well as the diagnostic. On the other hand, the results of image quality scores made by three radiologists (i.e., X, Y and Z) are given in Tables 4 and 5, respectively for the HSG and RUG procedures.

Table 3: Mean patient kerma area product (KAP) for each filter and percentage reduction in KAP for the HSG and RUG

Filter Thickness	HSG (Gy cm^2) Mean	SD	Range	Reduction in dose (%)	RUG (Gy cm^2) Mean	SD	Range	Reduction in dose (%)
0T	2.89	0.92	1.45 - 4.43		5.03	1.44	2.4 - 6.70	-
1T	2.22	0.09	2.12 - 2.33	23	3.93	1.32	3.02 - 5.92	22
2T	1.7	0.64	0.98 - 2.76	41	2.35	0.37	1.78 - 2.96	53
3T	1.3	0.25	1.08 - 1.67	55	1.98	0.45	2.79 - 1.36	61
4T	1.1	0.32	0.76 - 1.74	62	1.65	0.37	1.07 - 2.06	67
5T	0.83	0.23	0.43 - 1.24	71	1.24	0.22	0.97 - 1.51	75

Table 4: Image quality scores for perceived change in clinical image quality without and with 1T, 2T, 3T, 4T and 5T additional filtration materials for the HSG procedures

Additional filtration thickness	Image quality criteria	Image quality score X	Y	Z	Mean
0T	A	36	41	40	39
	B	38	41	40	40
	C	36	42	38	39
	D	33	29	8	23
	E	37	39	37	38
1T	A	30	33	35	33
	B	31	31	35	32
	C	29	37	36	34
	D	18	14	13	18
	E	31	34	34	33
2T	A	33	36	34	34
	B	33	36	39	36
	C	35	37	34	35
	D	24	24	17	22
	E	36	34	23	31
3T	A	30	35	36	34
	B	29	35	36	33
	C	27	31	34	31
	D	14	28	24	22
	E	28	28	38	31
4T	A	36	33	35	33
	B	35	33	36	35
	C	27	31	35	31
	D	8	26	17	17
	E	32	30	36	33
5T	A	32	37	32	34
	B	25	35	35	32
	C	23	33	31	29
	D	14	23	10	16
	E	33	35	33	34

From the tables, the observed small variations in mean image quality scores across filtration groups for presence of perceived difference in image quality between the images with additional filtration (1T, 2T, 3T, 4T, and 5T) and without additional filtration, indicate that the uses of additional filtration do not have significant changes in clinical image quality. The observed small variations in mean image quality scores across filtration groups were largely attributed to other technical factors such as under exposure, poor reproduction of fimbrialrugae, poor mucal outline rather than the poor image quality.

Some of examinations in each filtration group were allocated some scores below three. The reasons recommended by the radiologists for the HSG procedures include density of the intrauterine cavity not uniform, visualization of sharp reproduction of intraperitoneal spillage not seen because of stricture, air bubbles and poor reproduction of fimbrialrugae. Of concern is the image quality criterion (d) on visually sharp reproduction of fimbrialrugae of which all the three radiologists scored 0 or 1 for majority of examinations. The reasons suggested by the radiologists include poor reproduction of fimbrialrugae, poor outlined, and completely not able to visualize the sharp reproduction of fimbrialrugae. The reasons suggested by the radiologists for scoring below three for the RUG procedures include urethra not visualized because of stricture, under exposure, parts of colon not visualized, difficult to visualize the urinary bladder, membrane strictures limit bladder visualizations, and poor mucal outline. All HSG examinations except two were classified as diagnostic. The remaining two were classified as non-diagnostic because of poor radiographic images and lack of details. These examinations were performed using 0 mm Cu (0T) and 0.3 mm Cu (4T). In case of RUG procedures, all the examinations except three were classified as diagnostic. The remaining three were classified as non-diagnostic because of poor diagnostic quality. These examinations were performed using 0.1 mm Cu, and 0.2 mm Cu.

Table 5: Image quality scores for perceived change in clinical image quality without and with 1T, 2T, 3T, 4T and 5T additional filtration materials for the RUG procedures

		Image quality score			
Filtration thickness	IQ criteria	X	Y	Z	Mean
0T	A	50	52	49	50
	B	51	53	50	51
	C	56	56	52	55
1T	A	33	32	33	33.
	B	33	35	33	34
	C	34	33	33	33
2T	A	31	35	33	33
	B	29	35	33	33
	C	34	33	34	34
3T	A	35	36	37	36
	B	35	36	38	36
	C	34	35	36	35
4T	A	33	33	35	34
	B	33	33	34	33
	C	32	32	29	31
5T	A	30	35	38	34
	B	30	34	39	34
	C	26	31	33	30

Conclusion

The effectiveness of additional X-ray beam filtration of copper and aluminium to reduce radiation doses to patients undergoing contrast–based X-ray fluoroscopy procedures of the hysterosalpigraphy and retrograde urethrography without appreciably compromising image quality has been investigated. In this study, both phantom and patient studies demonstrated that the use of additional beam of up to 0.35 mm Cu + 1 mm Al thickness could lower the radiation doses to patients undergoing HSG and RUG procedures without significant compromising the image quality. The independent radiologists perceived no significant change in clinical image quality with added filtration. On introducing 0.35 mm Cu (+ 1 mm Al) in clinical practice, the mean values of KAP per examination for the HSG was reduced by 71%, from 2.89 to 0.83 Gy cm^2, while for the RUG was reduced by 75%, from 5.03 to 1.09 Gy cm^2. In light of the above, the use of additional copper filtration could reduce radiation doses to the patients undergoing HSG and RUG procedures considerably without significantly compromising image quality.

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