Jurnal Sains Kesihatan Malaysia **14**(2) 2016: 103-109
DOI : http://dx.doi.org./10.17576/JSKM-2016-1402-12

Artikel Asli/*Original Articles*

Radiation Dose Management in Fluoroscopy Procedures: Less is More?
(Pengurusan Dos Radiasi Semasa Prosedur Fluoroskopi: Lebih Rendah Lebih Baik?)

SITI FARIZWANA MOHD RIDZWAN, S. ELAVARASI SELVARAJAH & HAMZAINI ABDUL HAMID

ABSTRACT

The aims of this study are (1) to determine the scattered radiation dose levels in routine fluoroscopy procedures and (2) to compare them with the equivalent chest x-rays and also (3) to monitor common techniques and radiation safety measures taken by the medical officers. The study covered a sample of 105 fluoroscopic procedures performed by 18 medical officers. Each officer wore a personal pocket dosimeter inside the lead gown during each procedure. A digital dosimeter was placed near the detector of the fluoroscopy unit while a survey meter was positioned at the control panel area to record the dose levels. There were 14 types of examination included in this study. The total number of images captured was found to be the highest in barium swallow examination with 115 images, almost five times higher compared to the common practices. The longest screening time was observed in barium enema examination which is 9.15 seconds. The median of the scattered dose level was the highest in barium meal examination (165.50 µSv) which is equivalent to 8.28 times of average dose impart by chest x-ray examinations. The number of images and the length of screening time depend on the competency levels of the medical officers. They capture as many images as possible to avoid missing any abnormalities, therefore it will always be better if the fluoroscopist is consulted during each case. They should also consistently practice essential protection by minimizing exposure time, maximizing distance from the source tube and utilizing the radiation shielding.

Keywords: Scattered dose; fluoroscopy; pocket dosimeter; screening time; competency

ABSTRAK

Tujuan kajian ini adalah untuk (1) menentukan tahap dos serakan sinaran di dalam rutin prosedur fluoroskopi, dan (2) membandingkannya dengan dedahan sinar-x semasa pemeriksaan radiografi dada serta (3) memantau teknik yang biasa digunakan oleh pegawai perubatan dan langkah keselamatan radiasi yang diambil. Kajian ini meliputi 105 prosedur fluoroskopi yang dijalankan oleh 18 pegawai perubatan. Mereka menggunakan dosimeter poket di bawah gaun plumbum semasa prosedur dijalankan. Satu unit dosimeter digital diletakkan berhampiran detektor unit fluoroskopi sementera sebuah meter survey ditempatkan di kawasan panel kawalan untuk merekodkan bacaan dos. Terdapat 14 jenis prosedur fluoroskopi yang terlibat di dalam kajian ini.Bilangan imej radiografi didapati sangat tinggi semasa pemeriksaan barium swallow iaitu sebanyak 115 imej, hampir lima kali lebih tinggi berbanding bilangan biasa. Pemeriksaan yang paling lama pula diperhatikan semasa pemeriksaan barium enema (9.15 saat). Median bacaan dos serakan adalah tinggi semasa pemeriksaan barium meal (165.50 µSv) yang bersamaan dengan 8.28 kali ganda daripada purata dedahan sinar-x semasa pemeriksaan radiografi dada. Bilangan imej radiografi dan masa pemeriksaan bergantung kepada tahap kompetensi pegawai perubatan. Mereka cuba mendapatkan seberapa banyak imej yang mungkin untuk mengelakkan terlepas pandang sesuatu abnormaliti. Maka, adalah lebih baik sekiranya setiap pemeriksaan fluoroskopi dibuat di bawah pengawasan pakar fluroskopi. Mereka harus juga konsisten mengamalkan perlindungan radiasi dengan mengurangkan masa pendedahan, memaksimumkan jarak dari sumber tiub dan menggunakan alat perlindungan radiasi.

Kata Kunci: Dos serakan; fluoroskopi; dosimeter poket; masa pemeriksaan; kompetensi

INTRODUCTION

Fluoroscopy is a type of medical imaging that shows a continuous X-ray image on a monitor to be reviewed by the physicians. The image is projected to a screen so that the movement of a body part or an instrument or contrast agent through the body can be viewed in detail. This examination provides a real-time X-ray projection imaging of dynamic processes as they occur. Fluoroscopy is performed for diagnostic imaging purposes by the visualization of patient anatomy and also for therapeutic purposes through interventional procedures (Nyathi et al. 2009). The diagnosis and treatment can be executed; for example, by viewing the gastrointestinal tract, guiding and directing the movement of the catheter through the vessels and ducts as well as assisting with the placement of the stents.

It carries some risks like the other X-ray procedures. The dose of radiation varies from patients to patients, depending on the individual procedure, patient size, exposure parameters such as kVp, mAs and time setting. For an example; a higher kVp setting is needed for a bigger sized patient to enhance x-ray penetration. However, every procedure may result in a relatively high radiation dose. The radiation is more pronounced in complex procedures such as placing stents or other devices inside the body which require the examination to be administered for an extensive period of time.

Radiation-related hazards associated with fluoroscopy include radiation-caused injuries to the skin and underlying tissues which occur briefly after the exposure, and radiation-induced cancers, which may take place sometime afterwards in life (US Food & Drug Administration (FDA) 2014). However, the chance that a person will experience these effects from a single fluoroscopic procedure is statistically very low (Balter et al. 2010).

Therefore, if the procedure is medically essential for the patient, the radiation threats are compensated by the benefits. In fact, the radiation risks are usually far less than other risks not associated with radiation like anesthesia or risks from the treatment itself. To decrease the radiation risk, fluoroscopy ought to constantly be carried out with the least possible exposure for the shortest time required (Kumar 2014).

This study aims to determine the scattered radiation dose levels in routine fluoroscopy procedures and to compare them with the equivalent chest x-rays, besides carrying out a surveillance on medical officers practices in our center. The results from the surveillance will be utilized in improving the healthcare management quality in fluoroscopy procedures in our department.

The procedures are usually performed by medical officers such as postgraduate students who most of the time carry out the procedure without the direct supervision of the fluoroscopist. The concern exists when they tend to capture as many images as possible to avoid missing any abnormalities. The fact that radiation will be attenuated as it traverses through tissue leads to the biological effects associated with radiation (LaTorre 1989). The probability of causing biological damage in tissues is not only restricted to high doses, but exists even at low dose levels.

MATERIALS AND METHODS

This cross-sectional study took place at the Department of Radiology in one of the tertiary teaching hospitals in Kuala Lumpur. All fluoroscopy procedures for the duration of four months were observed using fluoroscopy machine (Toshiba KXO-80G). Scattered radiation dose reading in the examination room was determined using a calibrated personal alarming dosimeter (RADOS RAD-60) which was placed in a pouch attached to an elastic tape. The pouch hanged from the arm of the x-ray tube. Another dosimeter was worn by the medical officer under their lead gowns. Scattered radiation dose at the control panel area was determined using a calibrated auto-ranging survey meter (451P Pressurized uR Ion Chamber).

Patient-related parameters were recorded in the data collection sheet for a four-month period. The parameters included were the age, gender, type of examination, number of images, clinician(s) performing the examination, radiographer(s) in charge, screening time, dose reading, kVp value, mAs value, grid and collimation usage.

The patient's age, gender and type of examination were obtained from the radiology examination request form. The number of images was found on the Integrated Radiology Information System (IRIS). Meanwhile, the data for screening time, kVp and mAs value, grid and collimation usage were gained from the control panel board. The rotation schedule for medical staff provided the name of the clinician and radiographer in charge for the duration of this study. All radiation doses were acquired from the dosimeter and survey meter which provided the real time measurement.

All the data were analyzed using SPSS Version 22.0 software, which contained tools for quantitative descriptive analysis, tables and chart builder features as well as the correlation test.

This paper was produced based on the routine clinical audit data collection in order to identify opportunities for improvement of our department services and medical postgraduates students' quality of radiology services. No ethical issues were related to this publication as it never involves any changes in the health services and management.

RESULTS AND DISCUSSION

This study managed to involve a total number of 105 patients who came to the unit to undergo fluoroscopy examinations by non-probability convenience sampling. The largest ethnic group recruited is Malay which is 62.86%, followed by Chinese (24.76%), foreigners (7.62%) and Indians (4.76%) (Figure 1); whereby 62.86% of them were female patients and 37.14% were male patients (Table 1).

The overall mean of the patient's age was 39.87 ± 21.46. The youngest patient recorded was a four-month old infant while the oldest was a 81-year-old patient. The mean age of the patients, according to the type of examination is tabulated in Table 1. There are 14 types of fluoroscopy examination captured during this study. The most frequent examination requested is a hysterosalpingogram (HSG), an X-ray test that examines the uterus and Fallopian tube area usually for infertile female patients. Other common examinations were micturatingcystourethrogram (MCUG), barium swallow and barium enema.

The results in Table 2 are elaborated below. Between the 14 types of examination, barium swallow showed the

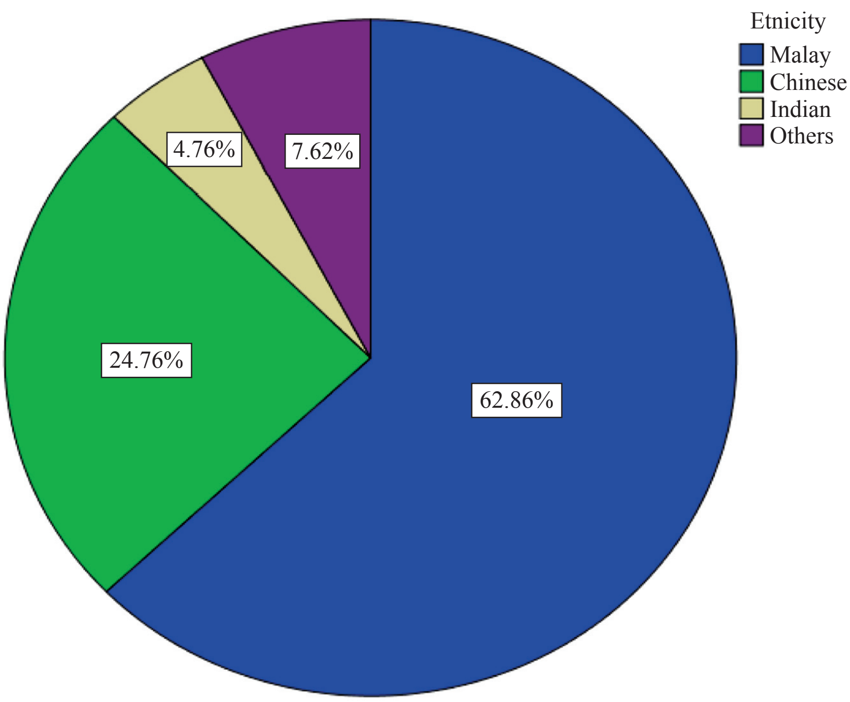

FIGURE 1. The fraction of the patient's ethnicity

TABLE 1. The distribution of gender and mean age of the patients included in the study by the type of examination

Type of Examination (N = 105)	Gender (N = 105)		Age (Mean ± SD)
	Male (n = 38) (37.14%)	Female (n = 67) (62.86%)	
HSG	0	41	31.27 ± 5.25
MCUG	8	2	5.38 ± 5.75
Ba Swallow	12	5	59.76 ± 7.55
Ba Enema	6	2	66.13 ± 6.47
Ba Meal	1	1	54.50 ± 9.19
Distal Loopogram	2	5	35.14 ± 32.26
Cystogram	3	3	58.50 ± 20.40
Urethrogram	1	1	61.00 ± 19.80
Fistulogram	2	1	26.67 ± 21.59
Upper GI	1	2	19.17 ± 17.08
T Tube	0	2	59.50 ± 24.75
Gastrografin Study	1	1	56.50 ± 4.95
Sialogram	1	0	59.00
DSG	0	1	49.00

highest number of images captured in one examination which is as eminent as 115 images with an interquartile range (IQR) of 71. The lowest number of images captured was found in HSG examination with the median of 9 images (IQR = 4).

In the barium enema examination, the longest screening time was documented by the median screening time of 9.15 seconds (IQR = 6.48). Whilst the shortest screening time was 0.50 seconds in dacryocystography (DSG) examination. The scattered dose received by the medical officers was detected to be in the range of 0.5 to 1.0 µSv during barium meal examination, T-tube cholangiography, upper gastrointestinal examination and gastrografin study, even though the dosimeter was placed inside their lead gown. Meanwhile, scattered dose in the examination room showed the highest median of 165.50 µSv in the barium meal examination and the lowest 1.00 µSv in DSG.

Table 3 outlines the analysis specifically for paediatric patients (age 18 and below). The total number of paediatric examinations is fifteen, involving MCUG, distal loopogram, fistulogram and upper gastrointestinal examination. The mean age of paediatric patients is 5.38 ± 5.72 for MCUG, 1.33 ± 0.58 for distal loopogram, 4 years old and 6 months old for fistulogram and upper GI, respectively.

TABLE 2. The tabulation of parameters measured for all fluoroscopy examinations

Type of Examination (N = 105)	Exposure Factor, Kilovolt Peak (kVp)	Exposure Factor, Miliamp Seconds (mAs)	Number of images	Screening time (s)	Doctor's Dose (μSv)	Scattered Dose (μSv)
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
HSG	86.0 (18.0)	1.3 (1.0)	9.0 (4.0)	1.80 (1.85)	0.0 (0.00)	9.00 (17.00)
MCUG	71.0 (11.0)	1.4 (31.1)	17.0 (18.5)	3.70 (3.45)	0.0 (0.00)	3.00 (6.00)
Ba Swallow	88.0 (29.0)	1.9 (2.3)	115.0 (71.0)	2.10 (1.35)	0.0 (0.00)	27.00 (29.00)
Ba Enema	85.0 (8.0)	1.6 (39.3)	25.0 (13.0)	9.15 (6.48)	0.0 (1.00)	99.00 (69.00)
Ba Meal	104.0 (10.0)*	2.3 (2.1)*	34.5 (41.0)*	4.10 (0.80)*	1.0 (2.0)*	165.50 (275.00)*
Distal Loopogram	83.0 (22.3)	1.35 (8.3)	15.0 (22.5)	5.40 (13.10)	0.0 (0.25)	26.00 (119.25)
Cystogram	86.0 (17.8)	0.85 (1.3)	13.0 (5.0)	2.40 (4.33)	0.0 (0.75)	18.50 (50.50)
Urethrogram	80.5 (7.0)*	1.4 (0.8)*	20.0 (6.0)*	3.20 (1.00)*	0.0 (0.0)*	17.00 (6.00)*
Fistulogram	89.5 (15.0)*	1.3 (1.5)*	17.0 (13.0)*	1.70 (0.50)*	0.0 (0.0)*	11.00 (18.00)*
Upper GI	80.5 (41.0)*	0.9 (3.6)*	18.0 (15.0)*	4.30 (1.50)*	0.5 (1.0)*	23.00 (38.00)*
T Tube	86.0 (0.0)*	0.9 (0.0)*	13.5 (3.0)*	3.65 (1.70)*	1.0 (2.0)*	11.50 (17.00)*
Gastrografin Study	95.5 (7.0)*	1.8 (1.3)*	37.0 (32.0)*	3.70 (1.00)*	0.5 (1.0)*	131.00 (78.00)*
Sialogram	125.0 (0.0)*	0.5 (0.0*	12.0 (0.0)*	3.60 (0.00)*	⸸	96.00 (0.00)*
DSG	90.0 (0.0)*	6.4 (0.0)*	37.0 (0.0)*	0.50 (0.00)*	0.0 (0.0)*	1.00 (0.00)*

* IQR cannot be computed, range value is reported instead to show the measurement of dispersion.
⸸ No record due to technical issue.

TABLE 3. The tabulation of parameters observed for fluoroscopy examinations involving paediatric patients

Type of Examination (N = 13)	Number of cases	Age (Years)	Exposure Factor, Kilovolt Peak (kVp)	Exposure Factor, Miliamp Seconds (mAs)	Number of images	Screening time (s)	Scattered dose (μSv)	Doctor's Dose (μSv)	Grid Usage	
		(Mean ± SD)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Yes	No
MCUG	10	5.38 ± 5.72	71 (12)	1.4 (31.1)	16 (11)	3.8 (2)	3 (5)	0 (0)	1	7
Distal Loopogram	3	1.33 ± 0.58	72 (19)*	1.0 (27.5)*	11 (54)*	2.4 (*)	1 (1)*	0 (0)*	1	2
Fistulogram	1	4.00	⸸	⸸	19 (0)*	1.7 (0.0)*	5 (0)*	0 (0)*	0	1
Upper GI	1	0.50	60 (0)*	0.9 (0.0)*	23 (0)*	4.9 (0.0)*	2 (0)*	1 (0)*	0	1

* IQR cannot be computed, range value is reported instead to show the measurement of dispersion.
⸸ No record due to technical issue.

From the table, the median number of images for all examinations is more than 10 with the highest images captured were in the upper GI examination; which also recorded the longest screening time, 4.9 seconds. Additionally, the dose received by the medical officers was contributed by this particular examination during the paediatric cases. The table also notes down on two cases where the removal of the grid is not applied during paediatric examination.

A scrutiny of the relationships among those parameters in adult and paediatric patients is illustrated in Table 4. In adults, a moderate positive correlation is found between screening time and scattered dose in the examination room and dose received by the doctors (r = 0.634 and 0.556; $p <$ 0.01). The same trend was observed in paediatric as well (r = 0.617 and 0.527; $p < 0.05$), in addition of a strong positive correlation between screening time and number of images ($r = 0.772$, $p < 0.01$).

The analysis reveals that, females are the majority of the subjects in this study, due to the most frequent procedure done during the study period; HSG. The HSG is carried out on females to examine infertility, recurrent miscarriages, post tubal surgery assessment, and assessment of the integrity of a Caesarean uterine scar (Chapman & Nakielny 2001). Our subjects comprised of patients as young as four-month old infant who underwent MCUG and as old as 81 years who underwent cystogram. MCUG is an examination on paediatric patients where the patient is asked to micturate during the examination. In the case of the infant, the medical staff would wait for the baby to urinate to take the images. Whereas, cystogram is commonly performed for any bladder study to investigate the system function, usually in adults (Chapman & Nakielny 2001).

The total number of images captured was found to be the highest in barium swallow examination, which is almost five times higher compared to the common practice which is around 24 images (Wall & Hart 1997). This examination aims to look for problems in swallowing motion and reflux along the gullet. Because of the rapid movement during swallowing activity, the medical officers tend to hastily capture the images in order not to leave out any abnormalities.

Another concern is regarding the screening time during examinations. The average screening time was recorded highest in barium enema examination compared to others. Barium enema is a procedure used to help diagnose diseases and problems that affect the colon and rectum (large intestine). The procedure took longer as it

TABLE 4. Correlation between parameters measured for paediatric and adults patients.

			Number of images	Screening time	Doctor's dose	Scattered dose
Adult patients (N = 90)	Number of images	Pearson Correlation	1	-.066	-.052	.101
		Sig. (2-tailed)		.534	.634	.341
		N	90	90	85	90
	Screening time	Pearson Correlation	-.066	1	.556**	.634**
		Sig. (2-tailed)	.534		.000	.000
		N	90	90	85	90
	Doctor's dose	Pearson Correlation	-.052	.556**	1	.595**
		Sig. (2-tailed)	.634	.000		.000
		N	85	85	85	85
	Scattered dose	Pearson Correlation	.101	.634**	.595**	1
		Sig. (2-tailed)	.341	.000	.000	
		N	90	90	85	90
Paediatric patients (N = 15)	Number of images	Pearson Correlation	1	.772**	.477	.647**
		Sig. (2-tailed)		.001	.072	.009
		N	15	15	15	15
	Screening time	Pearson Correlation.	772**	1	.527*	.617*
		Sig. (2-tailed)	.001		.043	.014
		N	15	15	15	15
	Doctor's dose	Pearson Correlation	.477	.527*	1	.680**
		Sig. (2-tailed)	.072	.043		.005
		N	15	15	15	15
	Scattered dose	Pearson Correlation	.647**	.617*	.680**	1
		Sig. (2-tailed)	.009	.014	.005	
		N	15	15	15	15

Correlation is significant at the 0.01 level (2-tailed).**
Correlation is significant at the 0.05 level (2-tailed).*

is usually done by a method called double-contrast. In a double-contrast or air-contrast study, the colon is first filled with barium through the anus and then the barium is drained out, depositing just a slight layer of barium on the wall of the colon. The colon is then occupied with air. This furnishes a detailed view of the inner surface of the colon, making it easier to see narrowed areas (strictures), diverticula, or inflammation. There are times where the patients cannot hold the gas and let it out, thus the air-filling step needs to be repeated. It contributes to the duration of the screening time. There are also some series of images taken and this involve over-couch radiography which gives more radiation compared to the screening (Lai et al. 2011). The additional radiation dose is received when the image capturing needs to be repeated due to some issues like less air in the colon, wrong exposure parameters chosen or inaccurate positioning.

On the other hand, the median value of the scattered dose level was the highest in barium meal examination, which is equivalent to 8.28 times of average dose imparted by chest x-ray examinations which is 20.0 μSv (Public Health England 2011). Barium meal examines further down the stomach and duodenum to the small intestine to investigate causes of haemorrhage, nausea or severe upper abdominal ache. All barium examinations, HSG, MCUG, and gastrografin study are using 'high kVp – low mAs' techniques to acquire fine details of the sites examined. In this study, high kVp value ranges from 80.5 to 125 kVp and mAs value as low as 0.5 to 2.3 mAs as tabulated in Table 2. High kVp defined the high penetrability of the x-ray through the tissues, hence the high scattered radiation to the medical personnel and in the examination rooms.

The result of this study summarized that scattered dose from patients during fluoroscopy examinations are not negligible. The long fluoroscopy time, particularly during interventional procedures, may result in patient doses that cause deterministic effects of radiation in patients (International Atomic Energy Agency 2007). The biological effects are categorized as deterministic effects such as skin erythema, epilation, death as a result of acute exposure and also cataract formation. Another one is stochastic effects which include inheritable damage, cancer and leukemia (Wagner et al. 1994).

Fluoroscopic procedures may accurately image and diagnose a wide range of conditions in both adults and children. However, radiographic examinations cannot be conducted using a "one-size fits all" approach. Paediatric patients, whose tissues and organs are still developing, are significantly more sensitive to radiation than adults (Brody et al. 2007; Strauss & Kaste 2006).

In accordance with Beer (2008), exposure factor suitable for child examination should be in the range of 60 to 80 kVp, where this audit proved compliances to the suggested range. On the contrary, this audit demonstrated violence in the number of images captured in MCUG; outlined as few as four to six images only, where we recorded as many as four times of it (Bolch et al. 2003). As a guideline, these views are essential in this particular imaging; control film (including symphysis pubis), early filling view, full bladder view, voiding urethra view and full-length view (Al-Imam et al. 2008).

Removable grids offer a large reduction in radiation dose of over 50 percent and are especially useful during pediatric procedures without degrading the image quality (Hernanz-Schulman et al. 2011). The grid can be applied easily with a touch of a button in many fluoroscopy machines (Lai 2011). Nevertheless, non-conformity for this parameter was found in two patients in MCUG and distal loopogram respectively. It is due to the negligence among doctors and radiographers. Hernanz-Schulman et al. (2011) concluded that children age of five and above should use anti-scatter grid while Schneider et al. (2000) preset it at the age of eight and above. In our case, those two patients are just four- and one- year old, respectively.

Regrettably, the data on fluoroscopy screening time is lacking in most of the published findings, unlike the data on exposure time. However, radiation doses are directly proportional to screening time, as we can see in the dose received by the doctors, solely in upper GI imaging where it recorded the longest screening time (New Zealand Ministry of Health 2010).

Radiation equipment operators need to be educated and alerted on dose optimization options through awareness campaigns, training curricula and continuing education programs (Nyathi 2012). Although medical officers received training in radiation safety and radiation biology, these topics are not part of most medical school or postgraduate medical residency training for other medical specialists using fluoroscopy. One simple and straightforward way of reducing the radiation exposure to patients and medical personnel is to reduce the frequency of examinations and procedures. Some of the best practices that may help include; collimate to the smallest region needed with the largest field of view possible, consider removing grids for paediatric screening, use alternate C-arm gantry angles to avoid high skin doses in long procedures, never place any part of the body in the primary x-ray beam and consider increasing added beam filtration beyond minimum requirements (Nyathi 2012).

It should be appreciated that for fluoroscopy and screening procedures, a reduction in patient dose will also result in a corresponding reduction in radiation worker dose (Russel 1986). According to Parry, Glaze and Archer (2001), "radiation dose delivered during fluoroscopy procedures is highly dependent on the operator." However, most manufacturers install a variety of tools on fluoroscopy equipment to help personnel adhere to the ALARA (as low as reasonably achievable) principle (Herrmann et al. 2012).

Personnel involved in the radiology suite, particularly the fluoroscopist, must be cognizant of the procedure time. It is imperative to maintain overall fluoroscopy time as low as possible for the reason that it lowers the patient exposure time due to less "beam on" time. There are policies requiring all fluoroscopy units to be equipped with a timer that alerts the operator to overload amounts of fluoroscopy, usually after 4.5 or 5 minutes of use (Pike 2014).

A drawback that is frequently encountered is not using the last image-hold feature (Parry et al. 2001). This is often one of the easiest and most effective ways to reduce a patient's radiation exposure. When fluoroscopy is stopped, an image continues to be displayed on the monitor. The last image-hold feature allows the image to be saved, thus reducing the need for another exposure.

An additional ordinary pitfall is incorrect distance between the patient and the image intensifier. The image intensifier should be placed as close to the patient as possible. Employing this practice will lessen both magnification and patient dose and also results in increased resolution and image quality (Parry et al. 2001). Whenever possible, collimation should be used to display only the area of interest, thus limiting the amount of tissue being exposed to radiation. Another common pitfall encountered in fluoroscopy suites involves not using the most appropriate techniques according to the procedure type and patient size. Ensuring the kVp and mAs are suitable for the procedure being performed, will so much facilitate best practices in fluoroscopy. For instance, if a barium study is being performed, a higher kVp would be engaged to regulate patient's body habitus and the elevated concentration of the contrast being used.

Patient safety should remain the primary focus during fluoroscopic procedures, but care must also be taken to guarantee that all personnel involved in the procedure are as protected as possible. By using apposite personal protective devices and monitoring, the staff involved in the procedure will receive the lowest possible dose (Miller et al. 2010).

CONCLUSION

Managing fluoroscopic use is not limited only to radiation safety practices, but involves equipment performance evaluation and quality control testing, besides the monitoring of radiation doses to patients and personnel, as well as training and education of the medical personnel. The number of images and the length of screening time depend on the competency levels of the medical officers. They must restrain from capturing many images as not to overlook patients' irregularities. It is advisable for them to consult the fluoroscopist during each case.

ACKNOWLEDGEMENT

The authors wish to thank all involved medical officers, radiographers, staff nurses and industrial training students in the Department of Radiology, UKM Medical Centre. A heartfelt gratitude goes to Mr M. Thirrummurthy from the International Languages Teacher Training Institute (IPBA) for his assistance in copy editing this article.

REFERENCES

Al-Imam, O.A., Al-Nsour, N.M. & Al-Khulaifat, S. 2008. Which is the best way of performing a micturatingcystourethrogram in children? *Saudi J. Kidney Dis. Transpl.* 19: 20-5.

Balter, S., Hopewell, J.W., Miller, D.L., Wagner, L.K. & Zelefsky, M.J. 2010. Fluoroscopically guided interventional procedures: a review of radiation effects onpatients' skin and hair. *Radiology* 254(2): 326-341.

Beer, M. 2013.Conventional radiography. In *ERS Handbook: Paediatric Respiratory Medicine* edited by Eber, E. & Midulla, F. Sheffield: The European Respiratory Society.

Bolch, W.E., Pomije, B.D., Sessions, J.B., Arreola, M.M., Williams, J.L. & Pazik, F.D. 2003. A video analysis technique for organ dose assessment in pediatric fluoroscopy: Applications to voiding cystourethrograms (VCUG). *Medical Physicis* 30(4): 667-680.

Brody, A.S., Frush, D.P., Huda, W. & Brent, R.L. 2007. Radiation risk to children from computed tomography. *Pediatrics* 120: 677-682.

Chapman, S. & Nakielny, R. 2001. *A Guide to Radiological Procedures*. 4th edition. London: W.B Saunders.

Hernanz-Schulman, M., Goske, M.J., Bercha, I.H. & Strauss, K.J. 2011. Pause and Pulse: Ten steps that help manage radiation dose during pediatric fluoroscopy. *AJR* 197(2): 475-481.

Herrmann, T.L., Fauber, T.L., Gill, J., Hoffman, C., Orth, D.K., Peterson, P.A., Prouty, R.R., Woodward, A.P. & Odle, T.G. 2012. Best practices in digital radiography. White Paper. *American Society of Radiologic Technologies*. Retrieved July 2015, from http://www.asrt.org/docs/defaultsource/whitepapers/asrt12_bstpracdigradwhp_final.pdf.

International Atomic Energy Agency (IAEA). 2007. Dosimetry in diagnostic radiology: An international code of practice. *Technical Report Series Number 457*. IAEA, Vienna.

Kumar, R.P. 2014. Fast Blood Vessel Segmentation for Surgical and Interventional Planning and Navigation. PhD Thesis. University of Oslo, Norway.

Lai, B.M.H., Fung, V.K.P., Shum J.S.F., Sy, A.N.L., Cheng, S.C.S. & Khoo, J.L.S. 2011. Radiation dose reduction for barium enema: an achievable improvement in patient care. *Hong Kong Journal of Radiology* 14: 212-217.

LaTorre Travis, E. 1989. *Primer of Medical Radiobiology*. 2nd Edition. Chicago: Year Book Medical Publishers.

Miller, D.L., Vano, E., Bartal, G., Balter, S., Dison, R., Padovani, R., Schueler, B., Cardella, J.F., de Baere, T. 2010. Occupational radiation protection in interventional radiology: A joint guideline of the cardiovascular and interventional radiology society of Europe and the society of interventional radiology. *Cardiovasc. Intervent. Radiol.* 33: 230-239.

New Zealand Ministry of Health. 2010. *Code of Safe Practice for the Use of X-rays in Medical Diagnosis.* Document CSP5 Version 1.3.ISSN 0110-9316.

Nyathi, T. 2012. Dose Optimization in Diagnostic Radiology. PhD Thesis. University of the Witwatersrand, Johannesburg.

Nyathi, T., Pule, M.L., Segone, P., van der Merwe, D.G. & Rapoho, S.P. 2009. A dose audit of fluoroscopy examinations at Charlotte Maxeke Johannesburg Academic Hospital: Analysis of preliminary results. *South African Journal of Radiology* 13(2): 24-28.

Public Health England. 2011. *Understanding Radiation: Dose Comparison for Ionising Radiation*. Retrieved from https://www.gov.uk/government/publications/ionising-radiation-dose-comparisons/ ionizing -radiation-dose-comparisons.

Parry, R.A., Glaze, S.A. & Archer, B.R. 2001. The AAPM/RSNA physics tutorial for residents – fluoroscopy: Patient radiation exposure index. *Radiographics* 21: 1033-1045.

Russel, J.G.B. 1986. Radiation protection in radiography in the U.K. *Br. J. Radiol* 59: 747-748.

Pike, S. 2014. Technical principles for diagnostic fluoroscopic procedures. Image Wisely®. *American College of Radiology*. Retrieved June 2015, from http://www.imagewisely.org/imaging-modalities/fluoroscopy/articles/pike-technical-principles.

Schneider, K., Perlmutter, N., Arthur, K., Cook, V., Horwitz, A.E., Thomas, P., Kramer, P., Montagne, J.P., Ernst, G., Kohn, M.M., Panzer, W. & Wall, B. 2000. Micturition cysturethrography in paediatric patients in selected children's hospitals in Europe: evaluation of fluoroscopy technique, image quality criteria and dose. *Radiat. Prot. Dosimetry* 90: 197-201.

Strauss, K.J. & Kaste, S.C. 2006. The ALARA (as low as reasonably achievable) concept in pediatric interventional and fluoroscopic imaging: Striving to keep radiation doses as low as possible during fluoroscopy of pediatric patients – a white paper executive summary. *Radiology* 240: 621-622.

U.S. Food & Drug Administration (FDA). 2014. *Radiation-Emitting Products.Fluoroscopy*. Retrieved June 2015, from http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MedicalX-Rays/ucm115354.htm.

Wagner, L.K., Eifel, P.J. & Geise, R.A. 1994. Potential biological effects following high x-ray dose interventional procedures. *J. Vasc. Interven. Radiol.* 5: 71-84.

Wall, B.F. & Hart, D. 1997. Revised radiation doses for typical x-ray examinations. *The British Journal of Radiology* 70: 437-439.

Siti Farizwana Mohd Ridzwan
S. Elavarasi Selvarajah
Hamzaini Abdul Hamid
Department of Radiology
Faculty of Medicine
Universiti Kebangsaan Malaysia Medical Centre
Jalan Yaacob Latif, Bandar Tun Razak, Cheras
56000 Kuala Lumpur, Malaysia

Corresponding Author: Siti Farizwana Mohd Ridzwan
Email address: farizwana@ukm.edu.my
Tel.: +603-91458289
Fax: +603-91456682

Received: November 2015
Accepted for publication: March 2016