Original article

Optimization of radiological doses to patients undergoing Intravenous Urography examinations in Addis Ababa, Ethiopia

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Abstract

Background: The effects of ionizing radiation should be a permanent concern in radiological practice, especially in exams with long duration and high exposure, like Intravenous Urography.

Objective: To calculate entrance surface dose as a result of radiation exposure of patients due to Intravenous Urography examinations.

Methods: A cross-sectional study was conducted on 145 adult patients above 16 years of age. Two government and two private hospitals were included in the study period from February 2012 - March 2012 in Addis Ababa, Ethiopia. **The characteristics of the radiographic equipment and the exposure data of each patient were recorded using designed format.** The radiation output of the x-ray machines was measured using Unfors RaySafeXI R/F detector. Doses delivered to patients were determined using appropriate equation. **The obtained data were analyzed using statistical software.**

Results: An average of 6.0 radiographs was obtained per patient**.** The mean entrance surface air kearma, entrance surface dose; Cumulative entrance surface air kearma; Cumulative entrance surface dose range from 3.9 to 7.6 mGy, 5.5- 10.1 mGy, 21.5 to 53.5 mGy and 29.9 - 74.3 mGy respectively.

Conclusion: The mean entrance surface dose recorded in this study (8.6mGy) was less than the diagnostic reference levels recommended by Commission for European Community (10mGy) and International Atomic Energy Agency (10mGy). These insure that the Intravenous Urography examinations performed in these hospitals were capable of achieving acceptable dose levels for patient safety. [*Ethiop. J. Health Dev.* 2014;28(3):202-210]

Introduction

Radiation doses from diagnostic radiology are the largest contributor of collective dose from all man-made sources of radiation (1). Diagnostic radiology and nuclear medicine procedures are the cause of about 88% of collective effective dose from man-made sources in the US (2-4). Although radiation exposure connected with these procedures cannot be avoided, there are means to reduce it as much as possible. Patient radiation dose from conventional radiographic procedures ranges from 0.1 mSv to 10 mSv, resulting in a collective dose to the population that can be significant (5).

Intravenous urography is an old and classic radiographic examination with roots to the early 1930s. The examination will normally be performed with several successive radiographs in the abdominal and pelvic region. The urinary tract does not show up well on ordinary X-ray pictures. Intravenous Urography (IVU) is useful in demonstrating small lesions in the urinary tract (papillary necrosis, medullary sponge kidney, uroepithelial tumors, pyeloureteritis cystic) (6). With intravenous urography, a contrast dye is injected into a vein ('intravenous' injection). The dye travels in the bloodstream, concentrates in the kidneys, and is passed out into the ureters. The dye blocks X-rays so the structure of the kidneys, ureters and bladder shows up clearly as white on X-ray pictures. No absolute contraindications to urography exist but caution should be observed. Death due to a reaction to contrast media is rare, the incidence being about one in 50,000 procedures. Adverse reactions of various types and severity occur in 5-8% of patients, but fewer than 2% of these are clinically important (7).

The procedures used, vary somewhat from one department to the other, but nevertheless it is a standard examination suitable for monitoring. The frequency of this examination has decreased during the last decade, mainly due to ultrasound diagnostics as an alternative examination method. Data based on complete registrations in Norway 1983, 1988 and 1993 shows a reduction in frequency from 19 to 9 per 1000 inhabitants in this ten-year period. At present the frequency in some of the Nordic countries is in the range 7-14 per 1000 inhabitants, or roughly 1 % of all examinations (8). IVU does involve up to 20 radiographs (mean of 8.2) (8), 9.3 film on average (9) and the average patient weight was 70 kg. For this reason, even if the intravenous urography frequency is only about 1% of the total number of examinations, its contribution to the collective dose is in the range of 5-11 % (10, 11).

In diagnostic radiology, periodic dose assessments should be made to encourage the optimization of the radiation protection of the patients. Dose measurements are

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required further to compare different radiological techniques and to comply with some international guidelines and regulations. During the last ten years many studies have been conducted on the radiation dose due to clinical X-ray examinations (12-15). These studies, in addition to many international researches, have reported wide variations in patient dose arising from specific X-ray examinations. Experiences from various national surveys have shown that there is a large variation of patient doses for the same examination up to a factor of 20 or more in different hospitals or even in different rooms (16-17). Reasons for these dose variations were complex but, in general, low tube potential, high mAs and low filtration were associated with high-dose hospitals (18).

During recent years, patient dose has become a major issue and because of the increasing awareness and greater realization of the effects of ionizing radiation, X-ray users are now more demanding of dose information and dose reduction (19).

Even though a total 752 Hospitals/Clinics were performing X-ray examinations in Ethiopia (20), radiation exposures to diagnostic x-rays are rarely known and documented in the country. There are no guidelines with respect to the maximum radiation dose that is permissible for different diagnostic procedures performed taking into account the social and the economic factors of the Nation (21). A study by Daniel *et al*. (22) in nine public hospitals evaluated the collective effective dose in IVU procedures using secondary data. There is no study on radiation dose level evaluation in diagnostic IVU procedure for optimization of patient protection. To the best of our knowledge this study is the first of its kind in Addis Ababa, Ethiopia. Therefore, the objective of the study was to come up with the estimation of Entrance Surface Dose (ESD) for patients undergoing Intravenous Urography examinations at two private and two public hospitals in Addis Ababa, for potential optimization of radiological doses.

Methods

This study was conducted during February 2012 to March 2012 at two government and two private hospitals in the Ethiopian capital Addis Ababa. All governmental/private hospitals were the source population while the study populations were patients who came to take diagnostic IVU examinations in four large private and governmental hospitals. The study utilized a cross-sectional study design. Four X-ray units of the hospitals were included in the study. The hospitals are hereafter referred to as: A, B, C and D hospitals. These hospitals were chosen because they had a considerable number of IVU procedures performed on daily basis.

Initially, self-administered questionnaires regarding each X-ray unit including manufacturer, model, film type and film speed information, socio demographic characteristics such as age, sex, body mass index(mass[kg]/(height[m])^2, abdominal thickness, mass [kg], height[m] of a patient and radiological technical variables (parameters) such as film to focus distance (FFD), film to skin distance (FSD), peak kilo voltage (kVp), tube loading (mAs), current (mA), exposure time (sec), number of exposures to IVU examination were prepared in English and distributed to the radiographers working in the target Hospitals. The completed questionnaires were checked for completeness and consistency and collected from the respective Hospitals.

The tube output measurement was taken by the principal investigator in a scatter-free geometry, for a peak tube voltage of 80 kV_p, exposure current–time product of 20 milli-ampere second (mAs) and a focus-to-detector distance of 100 cm, using unfors RaySafeXI R/F detector. This dosimeter was calibrated by the manufacturer and reported to have accuracy better than 5%.

The annual average number of patients diagnosed in each year using IVU examination before the study period was about 2,160. The sample size was determined based on Cochran's formula to be 145 patients. Proportional allocation was used to allocate the total sample size to each hospital. Even though, film fault analysis was not performed during the research period; radiographs (films) with acceptable quality and good diagnostic information were selected by the radiographers for this research. This ensured that all dose levels used were representative of diagnostic image.

Entrance surface dose: ESD is defined as the absorbed dose to air on the X-ray beam axis at the point where the X-ray beam enters the patient or a phantom, including the contribution of the backscatter (IAEA, 2007). The ESD was calculated in the present work using the following relations.

$$ESD = (o/p) * mAs * (\frac{kVp}{80})^2 * (\frac{100}{FSD})^2 * BSF$$

Where O/P is the tube output per mAs measured at a distance of 100 cm from the tube focus along the beam axis at 80 kV_p kV is peak tube voltage recorded for any given IVU X-ray examination**,** mAs is the tube current–time product, FSD is the focus-to-patient entrance surface distance and BSF is the backscatter factor. The BSF depends on the X-ray spectrum and beam size. In this study, since the BSF variation for the field sizes and kVps used for these examinations were not significant BSF equal to 1.39 (9) was used for all projections. The cumulative ESD (CESD) for the whole examination of a patient was obtained by multiplying ESD per exposure with the number of exposures to a patient.

The obtained data was recorded and analyzed using statistical software. Before conducting the study, the research project was ethically cleared by the Institutional Review Board of the College of Health Sciences, Addis Ababa University. All participants were informed about the purpose of the study and confidentiality of information. Finally, verbal consent was obtained from each participant.

Results

In this study 145 adults [(70 (48%) females and 75 (52%) males] were included. Out of145 adult patients 70 adults [32(46%) females and 38(54%) males] were from government hospitals while 75 adults [38 (50.7%) females and 37(49.3%) males] were from private hospitals. In Table 1, characteristics of the observed X-ray units and image processing are given for the hospitals. The three hospitals, hospital A, B, and D were using a blue sensitive 200 speed film screen combination while hospital C was using a 400 speed green sensitive film screen combination.

In Table 2 the patient data, recorded value of radiographic parameters, number of exposure (film) per patient are provided. The ages of the patient included in hospitals A, B, C, and D were 37 (18 -59), 38 (19 - 84), 39 (18 - 74), and 34 (17 -55), respectively. For all hospitals, the height, weight, and body mass index (BMI) were given. The mean mass of patients in hospital A, B, C and D were found to be 62, 72, 60, 66 kg respectively. The mean numbers of films per patient, including the control radiographic image used for diagnostic purpose, were 6.9, 5.6, 5.3 and 6.5 in A, B, C and D hospitals respectively. The lowest kVp was observed at hospital C 74.6(66, 97) having a minimum value of 66 kVp while the highest kVp was also observed at hospital B with a value of 98 kVp.

In Table 3, the summary of Entrance Surface air kearma (ESAK), cumulative Entrance Surface air kearma (CESAK), entrance surface dose (ESD), cumulative entrance surface dose (CESD) and dose area product (DAP) are given for adult patients examined in government and private hospitals. In Table 4 the descriptive statistics of ESD of this study together with related studies in some other countries and recommended international DRLs are documented.

Table 1: **Characteristics of fixed x-ray units, film screen combinations, and image processing in the health institutions**

		Private Hospitals		Government Hospitals	
		A	**B**	**C**	**D**
X-ray Units	Manufacturer	Shimadzu Japan	Villa Viromatic	Shimadzu Japan	COMET AGCH Switzerland
	x-ray generator	Three phase	Three phase	Three phase	Three phase
	Total filtration	2.53 mm Al	2.534 mm Al	2.53 mm Al	2.55 mm Al
	Output at 80kv(mGy/mAs)	0.0966	0.0352	0.1204	0.1022
	Image reception	Analogue	Analogue	Analogue	Analogue
	Anti-Scatter Grid	Adjusted	Adjusted	Adjusted	Adjusted
	Automatic Exposure Control (AEC)	Not adjusted	Not adjusted	Not adjusted	Not adjusted
Image Processing	Image processor	Manual	Manual	Manual	manual
	Dark room	Available	Available	Available	Available
	Period Replacing chemical of film developer	Every 8- 9 Days	Every 10 Days	Every 10 Days	Every 8 Days

Table 2: **Adult patients' data, value of radiographic parameters as average (minimum – maximum) in respective hospitals.**

		Patient data					Radiographic Parameters			
Hospital	**Sample Size**	**Age (year)**	**Height (m)**	**Weight (kg)**	**BMI (kg/m^2)**	**Patient Thickness (cm)**	**kVp**	**mAs**	**FSD (cm)**	**Number of films in an exam**
A	28	37	1.64	62.85	23.3	16.9	76.5	64.7	88.1	6.9
	*12F/16M	(18-59)	(1.38, 1.81)	(44- 88)	(18.29- 33.29)	(10-25)	(70 - 85)	(50-80)	(80-95)	(6-9)
B	42	38	1.67	72	25.7	22.4	90.3	87.1	82.6	5.6
	*20F/22M	(19-84)	(1.38-1.82)	(47-98)	(17.7-33.1)	(11-28)	(83-98)	(60-120)	(77-94)	(5-9)
C	51	39	1.61	60	23.1	16.5	74.6	32.4	88.5	5.3
	26F/25M	(18-74)	(1.45-1.80)	(35-95)	(15.6-33.1)	(11-30)	(66-97)	(24-48)	(75-94)	(4-8)
D	24	34	1.68	66	23.5	20.4	75.9	47.0	84.6	6.5
	*(12F/12M)	(17 - 55)	(1.53 –1.83)	(50 - 89)	(17.1 –34.2)	(16 - 30)	(70 – 80)	(36 – 62.5)	(75 - 89)	(5 - 9)

*F stands for female and M for Male

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Table 3: **Summary of descriptive statistics of dose quantities ESAK & CESAK and ESD, cumulative ESD; and DAP given for adult patients examined in government and private hospitals**

	A					B				
	ESAK (mGy)	**CESAK (mGy)**	**ESD (mGy)**	**CESD (mGy)**	**DAP (Gy. cm^2)**	**ESAK (mGy)**	**CESAK (mGy)**	**ESD (mGy)**	**CESD (mGy)**	**DAP (Gy. cm^2)**
Mean	3.9	21.5	5.5	29.9	13.7	7.3	47.5	10.1	66.0	32.0
St deviation	2.2	14.2	3.0	19.7	6.7	1.7	14.5	2.4	20.2	9.9
Minimum	1.9	9.1	2.7	12.6	6.5	4.3	22.5	6.0	35.7	18.9
1st quartile	2.4	12.4	3.4	17.2	9.4	5.8	34.7	8.0	48.2	25.9
Median	2.8	14.7	3.9	20.4	11.4	7.1	46.8	9.9	65.0	28.8
3rd quartile	4.7	24.6	6.6	34.1	16.2	7.8	53.3	10.9	74.1	34.9
Maximum	11.9	71.1	16.5	98.9	40.8	10.4	92.5	14.5	128.6	66.0
			C					**D**		
Mean	5.9	32.9	8.2	45.7	20.3	7.6	53.5	10.6	74.3	32.9
St deviation	1.7	10.4	2.4	14.4	5.7	2.5	20.6	3.4	28.7	11.3
Minimum	2.8	17.3	3.9	24.0	12.0	4.3	26.2	5.9	36.4	20.8
1st quartile	4.6	23.8	6.4	33.1	15.9	5.8	39.0	8.1	54.2	23.4
Median	6.2	32.4	8.6	45.1	18.7	6.5	45.8	9.0	63.7	28.4
3rd quartile	6.8	39.6	9.5	55.1	24.6	9.3	66.7	12.9	92.7	41.1
Maximum	10.7	56.4	14.9	78.4	35.8	13.0	103.7	18.0	144.3	58.5

Table 1: **Descriptive statistics comparisons of this study results (adult patients) with international studies and International DRLs ESD (mGy) per exposure and mean (range) of exposure and radiographic parameters**

	This Study	**Sudan (Halato *et al*, 2010)**			**Ireland**	**Italy**	**International DRLs**	
					Johnson and Brannan (2000)	**Compagnone *et al.* *(2005)***	**IAEA (1996)**	**CEC (1996)**
		A	**B**	**C**				
Mean	8.6	3.21	1.6	3.16	_	_	_	_
St dev	2.8	1.2	0.83	0.98	_	_	_	_
Minimum	2.7	1.68	0.76	1.92	_	_	_	_
1st quartile	6.5	2.7	1.06	2.56	_	_	_	_
Median	7.8	3.05	1.35	2.88				
3rd quartile	9.9	3.46	1.71	3.36	6	3	10	10
Maximum	18.0	6.75	4.49	6.26	_	_	_	_
Exposure and radiographic parameters								
Mean (Range) kVp	79. 3 (66 - 98)	72 (62- 83)	75 (65- 85)	67 (62-80)	_	_	_	(50 – 90)
Mean(Range) mAs	57.8 (24 -120)	22 (14-36)	21 (14-30)	32 (28-40)	_	_	_	_
Mean (Range) FSD	85.95 (75-95)	69 (60-76)	71 (57-79)	62 (58-73)	_	_	_	_

Discussion

The results obtained in the present study indicate considerable variations in patient exposures among hospitals, even between two technologically similar X-ray units. As a result, patient doses differ from one institution to another. As shown in table 3, the mean ESAK ranges from 3.9 to 7.6 mGy while the mean ESD ranges from 5.5 to 10.1 mGy. The mean CESAK ranges from 21.5 to 53.5 mGy and the mean CESD varies between 29.9 and 74.3 mGy. The variations of doses among the different radiological departments studied may be attributed to inter-patient variations and technical factors such as differences in patient weights, exposure parameters, radiological technique, focus-to-film distance, total filtration, number of films and processing conditions. In hospital D, the radiographers use 30x40 film size which cause larger field areal exposure for all adult IVU procedures whereas in hospital A, the patients were more exposed per examination compared to other hospitals. Within hospitals there was a wide range of output: 0.0352 - 0.1204 mGy/mAs. The tube voltages vary from 66 to 98 kV, tube loading extends from 24 to 120 mAs while focus to skin distance varies from 75 to 95 cm. The number of exposures, the use of different film size and the variations in the skills of the radiographers were also the causes of patient dose variations among and within hospitals. The mean number of exposures observed in A, B, C, and D hospitals were 6.9, 5.6, 5.3, and 6.5 respectively. The tube voltage was manually set for adult patients in the government hospitals: D= (70 - 80 kVp), C= (66- 83 kVp) (except for one patient who received 97 kVp) and for private hospital A= (70 – 85 kv). These fell within the range of the recommended tube voltage by CEC (22) i.e. 50- 90 kv. However, in private hospital B, which had (83 - 98 kv), about 75% of the set voltage was out of the CEC (23) recommendations of 50-90kv. Moreover, as shown in table 2, private hospital B, which had low x-ray machine output (0.0352 mGy/mAs) high tube voltage range 83 - 98 kVp and high tube loading (60 - 120 mAs), was compared to government hospital D= (70- 80 kVp), government C hospital (66-83 kVp, except for one patient who received 97 kVp). In private hospital A (70-85 kVp) high machine outputs of (0.0966 mGy/mAs) a lower mean tube voltage of 76 kVp and mean tube loading of (32.4-65.5 mAs) with similar focus to film distance, FFD = 105 cm were used. In government hospital C, a lowest mean dose was recorded due to the lowest mean kVp, lowest mean mAs and lowest number of exposures vis-a-vis other hospitals. About 24% of mean ESD of private hospitals A and B was greater than the mean ESD of government hospitals C and D. As shown in Table 2, the mean values of ESD in all the health institutions, except for hospital D, were greater for males than they were for females. Thus generally females get lower mean dose than males due to the lower mean kVp, and mean mAs.

As shown in table 4, the mean value of ESD abdomen AP projection before and after contrast media was intravenously given to the patients was 8.6 mGy which is 14% lower than the reference levels of 10 mGy recommended by CEC (1996) and IAEA (1996). Moreover, the mean result of ESD in government hospital C (5.5 mGy) was about 8% lower than the Ireland ESD DRL of 6 mGy. This implies that hospital C was performing well in terms of radiological practice compared with other hospitals investigated in the study, due to the usage of high speed film - screen combination.

When the mean ESD results of this study were compared with three Sudanese hospitals, they were about 200% greater. This may be due to lower tube output (0.025 - 0.037 mGy/mAs) at 70 kVp, use of faster film-screen combination green type 400 speed, use of lower tube loading mean (21-32 mAs) and use of lower backscatter factor 1.35 (18) by Sudanese hospitals as compared with the findings of this study. However, the lower tube voltage of mean range from 67-75kVp and the lower FSD factors, which caused more doses, were dominated by the former higher radiographic parameters. The ESD in the findings of this study is 43% greater than DRL in Ireland (23) and 187% greater than DRL in Italy. While the mean ESD obtained in this study 8.6 (2.7-18.0 mGy) is less than DRLs of CEC and IAEA recommendations (25-26).

Any procedure that uses radiation can increase an individual's (patient's) risk of developing cancer. However, the chance of developing cancer from the radiation used during a urogram is low (6). The dose of radiation from the X-rays is small, compared with the dose you receive from natural background radiation in everyday environment. It is assumed that the radiographer will always use the smallest amount of radiation needed to get the best images to diagnose conditions (6). It is well known that different tissues and organs have different radio-sensitivities and that overall, females are more radiosensitive than males when it comes to cancer induction. The same is true for young patients (increased radio-sensitivity) as compared to older patients. For example, the lifetime attributable risk of lung cancer for a woman after an exposure of 0.1 Gy at age 60 is 126% greater than the value for a man exposed to the same dose at the same age (27). If a forty-year-old man is exposed to radiation, his risk of lung cancer is 17% greater than if he was exposed to the same radiation dose at age 60. These general aspects of radio-sensitivity should be taken into account in the process of justification and optimization of IVU because in some cases, the level of radiation doses may be relatively high for several organs. There are also individual genetic differences in susceptibility to radiation-induced cancer and they should be considered in specific cases involving relatively greater doses based on family and clinical history (28-31).

Patient radiation dose is a very important parameter to control the quality of the X-ray services in hospitals. Dose monitoring helps to ensure the best possible protection of the patient and provides an immediate indication of incorrect use of technical parameters or equipment malfunction. This study demonstrated that the method used here for estimating ESDs could be an alternative reliable and cheap method for patient dose monitoring in the everyday routine of a diagnostic radiology department. From the study we concluded that radiation exposure of IVU examination can be optimized by reducing both the number of IVU radiograph, the radiographic exposure parameters in particular tube current exposure time product (mAs) and using fast film – screen combination. Finally, we recommend that, the findings of the present work can be used as a baseline upon which future dose measurements may be compared. The results would also be useful to national and professional organizations. They are expected to encourage further dose surveys in the area of IVU examinations that will eventually lead to possible establishment of diagnostic reference levels.

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