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RESEARCH ARTICLE

A Mathematical Approach Evaluation of Dose Area Product (DAP) Using to Patients Undergoing Intravenous Urography Examinations in Addis Ababa, Ethiopia

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Abstract

Patient dose evaluation is one of the quality assurance programs. Dose area product is a product of surface area of patient that exposed to radiation at the skin entrance multiplied by the radiation dose at the surface. This research focused on a dosimetry, DAP, for specific X-rays examination which is known as Intravenous Urography examination. A cross-sectional study was conducted on 145 adult patients age above 16 years examined using IVU in Addis Ababa, Ethiopia at two public and two private hospitals during February 2012-March 2012. The type of X-ray tubes with their outputs (measured using Unfors Ray Safe XI R/F detector) and the exposure parameters for each patients were recorded. The DAP to patients were estimated using mathematical equation. The recorded data was analyzed using statistical software. It was obtained that mean DAP (Gy cm^2) per examination within hospitals ranged from 13.7 Gy cm^2 to 32.9 Gy cm^2. The mean value of this study DAP (24.7 Gy cm^2) per examination which was greater than most of the published results and National diagnostic reference levels. These insure that the Intravenous Urography performed in the some of the hospitals were not capable of acceptable dose levels for patient safety. Therefore, to achieve a lower value of DAP per examination to a patient; a quality assurance program should be done in the hospitals to minimize the number of films per exam and to use appropriate exposure factors to get quality radiographic image for diagnosis.

Keywords

Radiation dose, Dosimetry, Diagnostic reference levels, Quality assurance program

Introduction

Patient dose evaluation is one of the quality assurance programs (QAP). This research focused on a dosimetry for specific X-rays examination which is known as Intravenous Urography (IVU) examination. IVU does involve a large number of radiographs. IVU is the examination of the urinary tract involving up to 20 radiographs (mean of 8.2) [1-3], 9.3 film on average [4]. For this reason, even if the intravenous urography frequency is only about 1.3% of the total number of examinations, its contribution to the collective dose is much greater, equal to about 11% [5,6].

Dose area product (DAP) is a product of surface area of patient that exposed to radiation at the skin entrance multiplied by the radiation dose at the surface. Measurement of dose area product is suitable for achieving optimum degree of safety during radiological examination of patient.

Also, DAP is useful for continuous quality assurance, as well as analysis of performance of X-ray machines. Dose area product could be measured by two methods, namely:

i. Direct measurement through the use of a transmission ionization chamber at the surface of the X-ray tube collimator; and

ii. By mathematical approach (indirect). The mathematical approach involves the product of

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irradiated area of the patient and radiation dose incident at the surface.

Many studies have been proposed to measure ESD and DAP in different countries and their results were compared with DRLs recommended by relevant organizations. Also, organizations such as the National Radiological Protection Board (NRPB) and International Atomic Energy Agency (IAEA) recommended the use of dose constraints or investigation levels to provide guidance for medical exposures [7]; IAEA [8]. It was also recommended that dosimetry should be performed regularly to evaluate dose for optimization of radiation protection of the patients in order to introduce Local DRLs [9]. DRLs also help to facilitate standardization and optimization within departments and attempt to reduce dose variations between hospitals.

There is no study on radiation dose level, DAP evaluation in diagnostic radiology in Ethiopia in general, specifically in Addis Ababa, the capital city. Therefore, the objective of the study was to come up with the estimation of Dose Area Product (DAP) for patients undergoing Intravenous Urography examinations using mathematical approach at two private and two public hospitals in Addis Ababa, for potential optimization of radiological doses. Moreover, it is to compare this dose with the international literature.

Methods

This 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: H1, H2, H3 and H4 hospitals. These hospitals were chosen because they had a considerable number of IVU procedures performed on daily basis. 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.

Self-administered questionnaires regarding each X-ray unit including manufacturer, model, film type and film speed information, socio-demographic characteristics such as age, abdominal thickness 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 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.

Dose Area Product (DAP) evaluation

The DAP is the product of absorbed dose to air multiplied by the irradiated area and is constant at any distance from the focus. The relationship between DAP and ESD for a given field size at FFD is given by the following equation [4,10].

$$DAP = \frac{ESD}{BSF} * \left(\frac{FSD}{FFD}\right)^2 * A(FFD) \quad (1)$$

The Dose Area Product per radiograph (film) was evaluated by using equations (1). For whole examination of a patient was obtained by summing the DAP per exposure of different field size (i.e., area at FFD, A(FFD)) of a film sizes (cm × cm) used: 30 × 40 cm^2, 24 × 30 cm^2 and 18 × 24 cm^2 used during examination. Entrance Surface Dose (ESD) to a patient including the contribution of the backscatter radiation, BSF [11]. ESD was calculated using the following relation and the published results from [12]:

$$ESD = (O/P) * mAs * \left(\frac{KvP}{80}\right)^2 * \left(\frac{100}{FSD}\right)^2 * BSF \quad (2)$$

The BSF depends on the X-ray spectrum and beam size. In this study, it was used the BSF equal to 1.39 [4] for all projections, since the BSF variation for the field sizes and kVps used for these examinations is not significant.

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

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

The Health institutions H1 and H2 (public hospitals) while H3 and H4 (private hospitals) all have three phases X-ray units. The manufacturer of the machines at H1 and H3 was Shimadzu Japan whereas at H2 is CMET AGCH

Table 1: Patients' data, output of x-ray machine, value of exposure parameters as average (min-max) in the hospitals.

Hospital Name		Sample Size	Patients' Data		Output Of X-ray Machine	Exposure Parameters		
			Age of patient (year)	Patient Thickness(t_p) in cm	(mGy/mAs)	Kvp (kv)	mAs	FSD (cm) = FFD (cm) - t_p (cm)
Public hospitals	H1	24	34 (17-55)	20.4 (16-30)	0.1204	75.9 (70-80)	47.0 (36-62.5)	84.6 (75-89)
	H2	51	39 (18-74)	16.5 (11-30)	0.1022	74.6 (66-97)	32.4 (24-48)	88.5 (75-94)
Private hospitals	H3	42	38 (19-84)	22.4 (11-28)	0.0966	90.3 (83-98)	87.1 (60-120)	82.6 (77-94)
	H4	28	37 (18-59)	16.9 (10-25)	0.0352	76.5 (70-85)	64.7 (50-80)	88.1 (80-95)

Table 2: Descriptive statistics of dose quantities ESD and DAP in the hospitals.

Descriptive Statistics	H1			H2			H3			H4		
	ESD (mGy)	Number of Films used	DAP (Gy. cm^2)	ESD (mGy)	Number of Films used	DAP (Gy. cm^2)	ESD (mGy)	Number of Films used	DAP (Gy. cm^2)	ESD (mGy)	Number of Films used	DAP (Gy. cm^2)
Mean	10.1	6.5	32.0	5.5	5.3	13.7	10.6	5.6	32.9	8.2	6.9	20.3
Std. deviation	2.4	-	9.9	3.0	-	6.7	3.4	-	11.3	2.4	-	5.7
Minimum	6.0	5	18.9	2.7	4	6.5	5.9	5	20.8	3.9	6	12.0
1st quartile	8.0	-	25.9	3.4	-	9.4	8.1	-	23.4	6.4	-	15.9
Median	9.9	-	28.8	3.9	-	11.4	9.0	-	28.4	8.6	-	18.7
3rd quartile	10.9	-	34.9	6.6	-	16.2	12.9	-	41.1	9.5	-	24.6
Maximum	14.5	9	66.0	16.5	8	40.8	18.0	9	58.5	14.9	9	35.8
Max/Min	2.4	1.8	3.5	6.1	2	6. 3	3.1	1.8	2.8	3.8	0.7	3

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Table 3: Descriptive statistics this Study DAP (Gycm²) result in comparison with the results of international studies.

	Hospitals of the current study				This study	Swizer-Land	ICRP [12]/ NGL (1996)	UK			Greece	Germany	Sweeden	Ireland	Montenegro	Norway
	H1	H2	H3	H4		Arou, et al. [14]		Hart, et al. [17] UK-2005 review	NRBP-W14 UK-2000 Review by Hart et al [17]	NRBP [6]	Yakoumakis, et al. [4]	Muller, et al. [19]	Holm and Leithz [18]	Carroll and Brennan [15]	Milatovic, et al. [20]	Grøn, et al. (2000)
Mean	32.0	13.7	32.9	20.3	24.7	-	-	-	14.5	16	11.7	10.17	-	-	19	22.4
St dev	9.9	6.7	11.3	5.7	8.4	-	-	-	-	-	-	-	-	-	7	-
Minimum	18.9	6.5	20.8	12.0	6.5	-	-	-	1.6	4.5	2.44	0.64	-	-	15	6.8
1st quartile	25.9	9.4	23.4	15.9	18.7	-	-	-	6.8	-	7.63	-	-	-	-	-
Median	28.8	11.4	28.4	18.7	21.8	-	-	-	12.2	-	9.3	-	-	-	19	19.2
3rd quartile	34.9	16.2	41.1	24.6	29.2		40/20	14	16	24	13.54	-	20	12	22	28.9
Maximum	66.0	40.8	58.5	35.8	66.0		-	-	90.3	39	41.84	47. 63	-	-	29	65.7
Exposure and radiographic parameters																
Mean (Range) Kvp	75.9 (70-80)	74.6 (66-97)	76.5 (70-85)	90.3 (83-98)	79. 3 (66-98)							60(50-70)		-		70-90
Mean (range) Films	6.5 (5-9)	(4-8)	6.9 (6-9)	5.6 (5-9)	6.1 (4-9)							3.7(2-9)		-		9
Mean (range) mAs	47.0 (36-62.5)	32.4 (24-48)	64.7 (50-80)	87.1 (60-120)	57.8 (24-120)							-		-		-

Swizerland, and at H4 was Villa Viromatic. The output (mGy/mAs) was determined in free air measurement for a focus-film distance (FFD) of 100 cm and tube-voltage setting of 80kv and tube-current of 20 mAs.

In this study 145 adults were included. Out of 145 adult patients 70(48%) adults were from private hospitals while 75(52%) adults were from public hospitals.

In Table 1, the sample size, the patient data, the output of the X-ray tubes and recorded value of radiographic parameters of the hospitals were shown. The mean (range) age of the patients included in H1, H2, H3 and H4 are 34(17-55), 39(18-74), 38(19-84), and 37(18-59) respectively. Moreover, for each of the hospitals to the corresponding number of patients the mean (range) values of patient thickness, output of the X-ray machines, and exposure parameters were shown in the table.

In Table 2, descriptive statistics of dose quantities ESD and DAP in Private Hospitals /H3, H4/ and Public Hospitals /H1, H2/.

In Table 3, descriptive statistics this Study DAP (Gycm2) result in comparison with the results of international studies.

Discussion

In Table 3, the comparisons of this study results of DAP (Gy cm^2) with other international studies and international DRLs were given. In this table, this study mean value of DAP estimated to the patients, 24.7 Gy cm^2 was 62% and 42% below the ICRP reference levels of 40 Gy cm^2 (ICRP, 2001) [13] and the Switzerland DRL of 35 Gycm^2 [14] respectively. In addition, this study result was 10% greater than the mean DAP in Norway [15,16] and 3% greater than UK DRL [17], 23.5% greater than the Nordic DRL (NGL, 1996), 54% greater than greater than the Sweden DRL 20 Gy cm^2 [18], 106% greater than the Ireland DRL12 Gy cm^2 [15]. These could be due to the set exposure parameters of diagnostically acceptable and longer FFD > 100 cm, a lower number of exposure per examination, utilizing technologically latest type of x-ray tube machine, using good type of imaging modality, use of automatic image processor, etc., which are not accessed in developing countries. This study mean DAP to patients was about 52% greater than the mean DAP of 11.7 Gy cm^2 in Greece [4]. The mean DAP, 10.17 Gy cm^2 in Germany [19] 59% greater than this study mean DAP result due to setting a softer tube voltage (50-70 kv) and a lower number of radiograph per examination, 3.7 including the plain abdominal film. The Mean DAP 19 Gy cm^2 in the developing country Montenegro [20] was 23% greater than this study mean DAP result, it could be attributed to the use of relatively lower tube loading, lower number 6 (5-7) radiographs per exam, softer mean tube voltage of 67 kv which was a lower mean tube voltage, 79.30 kv, and a lower tube output of 0.08 mGy/mAs than this study.

The mean DAP (24.7 Gy cm^2) per examination and third quartile DAP (29. 2 Gy cm^2) per examination values of this study were greater than most of the published results and national diagnostic reference levels. These insure that the Intravenous Urography performed in the some of the hospitals were not capable of acceptable dose levels for patient safety. Therefore, to achieve a lower value of DAP per examination to a patient; a quality assurance program (QAP) should be done in the hospitals to minimize the number of films per exam and to use appropriate exposure factors for the best of diagnosis of quality radiographic image.

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