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Evaluation of Exposure Index Values for Conventional Radiology Examinations: Retrospective Study in Governmental Hospitals at West Bank, Palestine

Muntaser S. Ahmad[1*], Mohammad Shareef[1], Mohammad Wattad[1], Nora Alabdullah[1], Mouath D. Abushkadim[1], and Ammar A. Oglat[2]

[1] Department of Medical Imaging, Faculty of Applied Medical Health, Palestine Ahliya University, Dheisha, Bethlehem, Palestine; [2] Department of Medical Imaging, Faculty of Applied Medical Sciences, Hashemite University, Zarqa, Jordan.

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Abstract

In the digital radiology system, radiologic technologists (RTs) can choose imaging parameters include kVp and mAs. The RTs received a feedback after acquisition an image in the form of Exposure Index (EI). The aim of the current study was to check if the EI values are within the range values recommended by the manufacturer (MREI) for radiological examinations that include the chest, abdomen, pelvis, spine, and extremities. Data was collected from 3,000 adult X-ray examinations taken from several government hospitals in Palestine. The information included patient gender, kVp, mAs, EI values, and the examination time. All examinations included in the study used grid. While the study excluded all images that contained implant or prosthesis. Descriptive statistical analysis was used to analyse the data, while the Mann–Whitney U test was used to detect statistically significant differences, P < 0.05. Some examinations showed the EI values outside the MREI ranges. The EIs in the chest AP examination was higher in the female group than males while other examinations have no difference between males and females. The EIs out of working hours were higher than in working hours, especially in chest (P<0.0001), abdominal (P<0.0001), pelvic (P =0.02) and spine (P =0.0005) exams. In the summary it has been proven that some of the examinations are outside the MREIs, with differences between the patient gender and the time of the examination. The retrospective study for the exposure index is very important in reducing the risk of radiation to patients.

Keywords: EI, MREI, kVp, mAs.

[*]**Corresponding author:** wmuntaser@gmail.com

Introduction

The development of radiation technologies, digital photography (DR) has become the most used technique compared with conventional radiology in the past two decades (Paulo, 2015)(Muntaser S. Ahmad, Rumman, Malash, et al., 2018). DR system allows to use varying values in the technical parameters kilo-voltage peak (kVp), milliampere (mA), and time(s). The DR system has a wide dynamic range of exposure latitude compared to conventional x-rays without affecting on the produced image quality (Vañó et al., 2017)(Moey & Shazli, 2018). To remove the noise level on image in DR system, the radiologic technologists (RTs) is forced to raise the image parameters. However, the increase in the image parameters produce a readable image (Takaki et al., 2016)(Muntaser S Ahmad et al., 2019). The extent of the increase in parameters increase radiation dose to patients. This phenomenon is known as exposure creep (Mc Fadden et al., 2018)(American College of Radiology, 2017). Therefore, the RTs should work to balance the imaging factors without overexposing to the patient at the same time the produced image be readable. Thus, there is a need to monitor the technical parameters to reduce the patient radiation dose which is exposed.

Over time, the exposure creep increases by the RTs. Therefore, the X-ray manufacturers have created an exposure indicator (EI), and that means the RTs indicates an overexposure or underexposure in the produced image (American Association of Physicists in Medicine, 2009). The EI is a numerical value that describes the estimated absorbing dose of the detector, which depends on the sensitivity and efficiency of the image receptor (IR) (Peck et al., 2015)(Delis et al., 2017). Specifically, the EI does not display the actual absorbed dose that patient was exposed (Shantel Lewis et al., 2019a)(Seeram & Brennan, 2016). However, it gives an impression of that amount (S. Lewis et al., 2019).

The EI is used as a quality control tool to check the image quality, because the EI is proportional to the square signal to noise ratio (SNR) (Takaki et al., 2016)(Martin et al., 2017). The EI values for radiological examinations vary according to the manufacturer, each of manufacturer has specific values for the EI. Therefore, an international standardized EI was developed by International Electrotechnical Commission (IEC) and the American Association of Physicists in Medicine (AAPM) in association with DR system manufacturers (Scott et al., 2016). By standardizing the EI values, a linear relationship was designed between the detector exposure and index value (Takaki et al., 2019).

Given these scenarios, the aim of the current study was to monitor the EI of government hospitals in West Bank to evaluate the RTs who working in these hospitals for choosing the suitable radiologic technique for helping to reduce exposure to the patient. By doing a retrospective evaluates of the actual EI obtained from the abdominal, chest, pelvic, and spine, and extremities examinations for real patients and comparing them with the manufacturer recommended standards.

Materials and Methods

Equipment

The current study was performed on taking X-ray images from three government hospitals in the West Bank, Palestine. The hospitals were distributed in different areas of the West Bank. All government hospitals use the same DR system and the same full picture archiving and communication system (PACS) environment. The authors preferred to keep the names of the hospitals anonymous for not revealing the names of RTs in those hospitals. Examination details for abdominal, chest, pelvic, spine, and extremities images were extracted using the Philips DR DigitalDiagnost system, which contains flat panel detector.

Data collection

A total of 3,000 adult patient samples were obtained from Januarys to March 2019. The data (age, gender, examination type, exam projection, kVp, mAs, actual EI, and manufacturer-recommended EI (MREI) were recorded for each case over 90-day. Recorded examinations consist of chest (n = 1305), abdomen (n = 261) and pelvis (n=66), spine (n=63), and extremities (n = 1305). All exposures are adjusted from the RTs point of view and do not follow the rules automatic exposure control (AEC). All examination details were retrieved from the hospital PACS. All patients under the age of 18 were excluded, and all cases that contained implants or prosthesis were also excluded. The actual EI were compared to the MREI. All selected examinations were used grid with the grid ratio [R] 8:1, and line frequency [N] is 36 lines/cm.

Ethics

An ethical permit was obtained from the Palestinian Ministry of Health to allow patients information to be taken in order to apply the study while keeping the patient's names anonymous.

Statistical Analysis

The data obtained was statistically analysed using IBM SSPS V.25. Descriptive statistics were used to summarize the characteristics of each data. A Mann–Whitney U test was used to find the statistically significant differences between male versus female patients and in hours versus out of hours working. The value percentage of not adhering to MREI was calculated. The significance level was 5%, median; tables were used to present and the sociodemographic data using pie chart.

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Results

Descriptive Statistics

The sample were contained on adult male (1687) and female (1313) patients. All the data was used in the EI analysis of the examinations were shown in the Table 1. Most of the examinations showed a deviation from MREIs where the table appears all the examinations contain overexposure and underexposure ratios.

Figure 1 shows that 52.7% of the actual EIs fall within the MR standard. The other half, 32.8% of the examinations were overexposure and 14.5 % underexposures than MREIs. EIs which has values less than 250 were included in the overexposure values, while values greater than 630 were included in the underexposure (Shantel Lewis et al., 2019a). The highest results for the overexposure were represented in upper extremities (Lat) examination while the lowest examinations were in shown in chest (PA). On the other hand, the chest Lat showed the highest results in underexposure and the upper extremities (Lat) examination the lowest percentage in the underexposure.

Statistically Significant Results

Patient Gender

There is no clear difference in EI between the patient genders, this is what Table 2 shows. Most of the examinations showed that female median is higher than males. Chest Anterior–Posterior (AP) exam showed a significant difference between both gender where P-value less than 0.05 (P= 0.04). Moreover, female patients showed has overexposures than males in extremities, pelvis, abdomen and chest Lat examinations.

In Hours and Out of Hours

Despite, the number of cases withi-n working hours is greater than out of hours, the median EI values for out of hours is higher than in working hours in most examinations; were chest AP (P < 0.0001); chest PA (P=0.01); Abd AP (P<0.0001); and spine AP (P=0.0005). However, the median EI values for pelvic examination within working hours is higher than out of hours (P=0.02) (see Table 3).

Discussion

The aim of the current study was to determine the extent of RTs commitment within the MREI ranges for various radiological examinations, including chest, abdomen, spine, pelvis, upper and lower extremities. Also, for determining whether the patient's gender and the time of its imaging have an effect on the EI values.

The results showed that most of the examinations fall outside the MREI ranges. Upper Extremities (AP) and (Lat) were the highest rates of overexposure ratio by 51.1% and 51.9%, respectively. Followed by chest AP examination with an 40.3% overexposure rate. These results are consistent with previous studies, and this indicates that the transition from conventional imaging to the use of techniques CR and DR can result to increases patient exposure (Vaño et al., 2007)(Nassef & Kinsara, 2017). Pelvic AP examinations show the lowest underexposure rates where the ratio indicates to 10%. However, this value should be shown with caution due to the small sample size.

The high percentage of overexposure, which is the upper extremities, causes great anxiety, because these examination are among the second most common radiographic examinations after chest exam (Paper, 2015)(Muntaser S. Ahmad, Rumman, Hjouj Mohammad, et al., 2018). The increased rate of the overexposure examinations in the upper extremities is related to the use of grid in imaging rather than not using it compared to

Table 1. Descriptive statistics of exposure index value distributions for the examinations included in this study.

Examination	Number (n)	Median	Exposure	
			% Over	% Under
Chest Anterior–Posterior (AP)	385	275.5	40.3	17.7
Chest Lateral (Lat)	280	259	23.5	25
Chest Posterior–Anterior (PA)	640	392	15.8	19.7
Abdomen Erect (AP)	261	305	28.6	19
Pelvis (AP)	66	284.5	30	10
Spine (AP)	20	304.5	37.5	12.5
Spine (Lat)	43	319	22.2	11.1
Upper Extremities (AP)	442	191	51.1	6.4
Upper Extremities (Lat)	443	195	51.9	3.7
Lower Extremities (AP)	210	285	33.8	15.4
Lower Extremities (Lat)	210	293	26.9	19.2
Total	3000		32.8	14.5

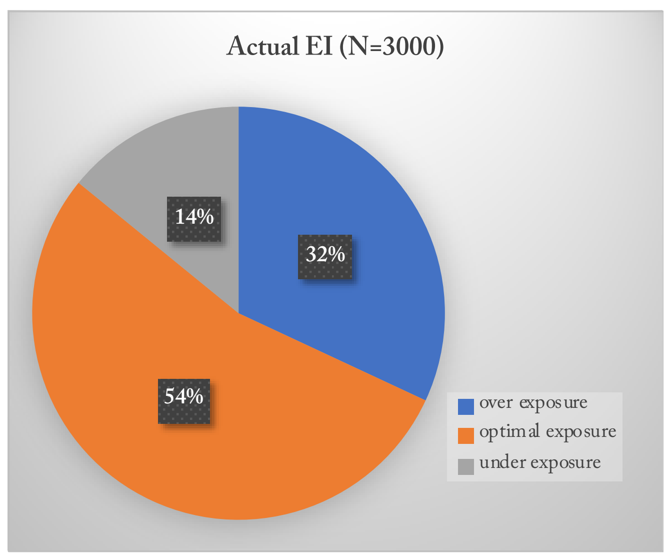

Figure 1. Actual exposure indicator compared to manufacturer recommended standards.

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Table 2. Exposure index values for each patient gender and examination type included in this study.

Examination	Gender	Number	Median	Exposure		
				% Over	% Under	p-value
Chest Anterior–Posterior (AP)	**M**	**254**	**320**	**34.1**	**26.8**	**0.04**
	F	131	184	52.4	0	
Chest Lateral (Lat)	M	188	320	20	14.2	0.723
	F	92	340	23.7	16.4	
Chest Posterior–Anterior (PA)	M	326	372	20.4	19.4	0.532
	F	314	416	10.1	20.2	
Abdomen Erect (AP)	M	87	238	15	24	0.582
	F	174	218	19	28	
Pelvis (AP)	M	8	305	14.3	0	0.202
	F	58	295	35.7	28.6	
Spine (AP)	M	13	266	40	20	0.820
	F	7	348	28.7	7.3	
Spine (Lat)	M	24	243	30	10	0.355
	F	19	330	12.5	12.5	
Upper Extremities (AP)	M	263	255	46.4	7.1	0.91
	F	179	140	57.9	5.3	
Upper Extremities (Lat)	M	254	241	50	5.6	0.26
	F	189	151	55.6	0	
Lower Extremities (AP)	M	135	292	31.1	11.9	0.28
	F	75	275	39.1	21.7	
Lower Extremities (Lat)	M	135	271	27.8	16.7	0.535
	F	75	374	25	25	
Total		3000				

Table 3. In and out hours exposure index values for all examinations type included in this study.

Examination	In hours (I)/out of hours (O)	Number	Median	Exposure		
				% Over	% Under	p-value
Chest Anterior–Posterior (AP)	I	257	226	0.6	5.3	<0.0001
	O	128	251	1.9	0.8	
Chest Lateral (Lat)	I	191	322	16.5	12.7	0.44
	O	89	344	20.2	14.9	
Chest Posterior–Anterior (PA)	I	323	374	16.9	17.9	0.01
	O	317	418	6.6	18.7	
Abdomen Erect (AP)	I	177	220	11.5	22.5	<0.0001
	O	84	239	15.5	26.5	
Pelvis (AP)	I	55	307	10.8	1.5	0.02
	O	11	297	32.2	27.1	
Spine (AP)	I	11	268	36.5	18.5	0.0005
	O	9	353	25.2	5.8	
Spine (Lat)	I	27	244	26.5	8.5	0. 55
	O	16	334	9	11	
Upper Extremities (AP)	I	266	257	42.9	5.6	0.71
	O	176	142	54.4	3.8	
Upper Extremities (Lat)	I	266	245	46.5	4.1	0.36
	O	177	154	52.1	1.5	
Lower Extremities (AP)	I	138	294	27.6	10.4	0.12
	O	72	281	35.6	20.2	
Lower Extremities (Lat)	I	138	273	24.3	15.2	0.35
	O	72	371	21.5	23.5	
Total		3000				

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film screen combination (FSC) and computed radiography (CR). In addition to the short distance between source image receptor distances (SID) (Sheridan & Mcnulty, 2016)(Pomerantz, 2013). Moreover, the reason may be due to the increased pressure on the RTs in imaging for a large number of patients, thus the RTs are forced to increase x-ray parameters on the patient to avoid returning the image again (Al-Tell, 2019)(Imaging & Journal, 2007). The relationship between focus to skin distances (FSD) and higher entrance skin doses (ESD) was explained. That's when it's changing the exposure factors and checking its effect on examination dose reductions (Gibson et al., 2011). It should be reduced the EIs by improving the exposure parameters on the DR device. It is important to take into account that the current study did not focus on the use of AEC and its effect on the EI.

It is important to observe EI to ensure quality assurance within the radiology units. In this study, the focus was on the effect of the patient's gender and time of imaging on performance on EI values. As for the gender of the patient, all the examinations except for the chest examination (AP), there is no difference between males and females on the EI. However, a chest AP exam showed an increase in females than in males. There is an unclear justification for this high exposure pattern in female patients. An earlier study suggested that inaccurate patient exposure patterns could lead to higher EI values and it was recommended improving exposure charts to reduce the dose of detector (Lanc & Silva, 2008). Improving the exposure chart can neutralize this bias of gender. It is noted in the previous literature that differences in male and female doses are closely related to monitoring AEC systems: the smaller differences in detected mean doses means the more sensitive AEC and it will be changed in the attenuation characteristics of the different patient groups (Web-Based Tools for Quality Assurance and Radiation Protection in Diagnostic Radiology, n.d.). The relationship between EIs and the increase in female patients should be checked in future studies under using DR devices. All other examinations were used AEC technique, while the chest AP examination did not used it, and because the location of the image plate under patients back directly especially patient on stretcher" non-ambulatory patient".

Regarding the timing of patient image, the study showed that there are statistically significant differences between working within hours and out of hours. As the EI values were increasing out of hours working. The reason for this is due to a shortage number of RTs in out of working hours, which start from 3 pm to 8 am next day. RTs may have to increase exposure values to avoid repeating images again under intense pressure. This is what was determined in the previous study (Shantel Lewis et al., 2019b). Also, the reason may be related to the number of experience years for RTs, as most of the RTs on the out of working hours have a little experience. However, the increase in the EI must be monitored to achieve the best results.

The aim of this study was to retrospectively analyse the EI for all examinations used in normal x-rays. It is not intended to assess the EI of the manufacturer or assessment the RTs in their performance, or assessment the patient doses. It was not possible to determine the size of the patient and the body part thickness because the study was a retrospectively. This would clarify some of the gender-related findings and their EIs.

Conclusion

In the summary, the results of the study show that there are many examinations that fall outside the framework recommended by the manufacturer. However, to determine the correct EIs from the manufacturer, an improvement should be made to the current system. It can be said with confidence that it is difficult to determine the inevitable reasons for the high exposure index commensurate with the patient gender and the time of the imaging, and the correct strategies must be taken in addressing this imbalance. The current study highlights the exposure that can be used to reduce a patient's dose.

Conflict of Interest

All authors declared no conflict of interests related to this article.

Disclosure

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