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RESEARCH ARTICLE

TOWARDS THE ESTABLISHMENT OF NATIONAL DIAGNOSTIC REFERENCE LEVELS (DRLS) IN PALESTINE: ASSESSMENT OF PATIENT DOSES IN COMMON ADULT CT EXAMINATIONS IN GOVERNMENTAL HEALTH SECTOR

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ABSTRACT

CT-scan is the most irradiating tool in diagnostic radiology. Patient's radiation protection must, therefore, be increased during CT-scan procedures. This requires a review and evaluation of the radiation dose in CT examinations. This study aims to assess the average doses, i.e. dose descriptors (CTDIvol and DLP)) in the West Bank- Palestinian governmental hospitals, for the most common adult computed tomography (CT) routine examinations. It compares its average doses and determines their variations from international assessments toward the adjustment of any improper dose level usage for the application of radiation m (ALARA) principle in our hospitals. The study applies a quantitative research method carried out on a representative sample, in which all the available data was taken from exams including (CTDIvol, DLP, other acquisition parameters). Our study was carried out in all routine examinations (Brain, Chest, Abdominopelvic, and Lumbar spine examinations), which were performed in the West Bank imaging facilities, in a period of three months. The study concluded with the following results. About 2998 CT scan examinations were collected and distributed. In each type of examination, great variations in the average doses, i.e. doses descriptors, CTDIvol, and DLP, from the other countries averages were observed. Enormous variations were noticed in the comparison among the West Bank imaging facilities, found in all facilities and examinations, except the abdominopelvicin which relatively low variations were detected. All these variations are closely related to the type of examination, protocol that is applied in each facility, scanning parameters, and the acquisition parameter selections by the technologist. This form of studies may help the Ministry of Health in the establishment of National Dose reference levels. CT technologists should not use the same protocols and technical factors for all patients at each individual examination and should take training courses to develop their expertise. Other studies should be implemented on private hospitals.

INTRODUCTION

According to US Food and Drug Administration (2017), medical imaging has led to improvements in the diagnosis and treatment of numerous medical conditions and abnormalities. Moreover, there are many types of modalities that have their special procedures, each of which uses different technologies and techniques. Among the various diagnostic medical imaging modalities, computed tomography is one of the most used methods. The Computed Tomography (CT), also known as computerized tomography or computed axial tomography (CAT), is a medical technology that uses special X-ray equipment to obtain image data from different angles around the body, and computer processing of the information to produce three-dimensional images while conventional X-rays provide flat two-dimensional images. CT images show a detailed view of cross-sections of body tissues and organs (Dowsett, 2009). The emerging technological advances in CT including multi-slice-CT (MSCT) make it an exceptionally valuable diagnostic imaging modality that is increasingly used (Hall, 2012). Simultaneously a significant increase in patient doses has been observed due to unjustified and inappropriate application of the progressively complex scan techniques (Valentin, 2007). CT-scan is known as the most important medical cause of human exposure due to ionizing radiations in diagnostic radiology. In its 2008, the annual report of the UN Scientific Committee (UNSCEAR) estimated that on the global scale CT-scans accounted for only 5% of medical imaging examinations versus 27% for chest X-rays, but contributed only 34% to the annual collective dose, that is 3% for chest x-ray. Therefore, patient radiation protection must be

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increased during CT-scan procedures. To reduce patient's exposition to x-rays, the principles of justification and optimization are the keystones (Ducou, 2013). The level of radiation dose received by patients undergoing CT examination depends on a number of factors, in particular the protocol used and equipment settings for the individual examinations (Brody et al., 2007). However, the reduction of patient dose requires a demanding application of the optimization principle which necessitates having a "dose investigation levels" as an optimization tool by which a simple standard for identifying situations where the patient's dose levels are abnormally high. Any user of ionizing radiation should refer to these Levels to evaluate his practice. (Malone,, 2012). According to ICRP (1996), several organizations currently providing guideline documents for CT scan examination monitoring including the ICRP, the Health Protection Agency in the UK (Board, 1999) and the American College of Radiology (Commission of European Communities, 1996).

Problem statement

In a Palestinian context, previous studies have shown great variability in the doses delivered to the patients in the medical CT examinations according to a graduation project of one of our students (Evaluation of the Radiation Doses for chest and abdomen CT-Scan at Beit Jalah Governmental Hospital-Bethlehem in Comparison with The Australian Reference Dose Levels, 2016). Correspondingly, during our practice at the various imaging facilities, we observed that there are no practical guidelines or standard protocols have been applied to the CT examinations to become optimized and quality controlled, in which a great inconsistency in exposure and technical factors between medical imaging facilities used in the West Bank, Palestine to produce a CT images.

Research objectives and questions

The study to be conducted is intended to determine the average doses of the four most common routine CT-scan examinations of adults in the West Bank governmental imaging facilities. In CT examinations, CT dose index (CTDIvol), and the Dose Length Product (DLP) are the most dosimetric quantities that are used as an indicator for the total of radiation received by patients (Najafi et al., 2015). Therefore, the study aims to quantify the average of CT dose indicators (CTDIvol and DLP) used for the communal four CT-scan examinations of adults (Brain, Chest, Abdomino-pelvic, and Lumbar spine) used at the West Bank governmental hospitals. It also aims to qualify the averages of CT doses used in the West Bank governmental hospitals by comparing them with the DRLs from four regional and international countries. The study addresses the following questions:

1. Do the various Palestinian medical centers use a standardized CT dose indicator, i.e. protocol, (CTDIvol and DLP)?
2. Do the CT dose protocols used by the local hospitals consider the variables of patient's age and gender?
3. What averages of CT dose do the indicators of the governmental hospitals show?
4. To what extent do the CT doses used locally meet the standards used regionally and internationally?

Significance of the study

The study counts. Locally, it bridges the gap in the literature. This small-scale study will be the first (up to the researchers' best knowledge) to investigate the CT scan dose protocols used by the various medical centers when dealing with the Palestinian patients. Academically, the researchers hope that the study contributes to knowledge. They hope that their humble work will be the preliminary point for establishing a national diagnostic reference levels (DRLs) for all the diagnostic imaging modalities that X-Rays are the imaging source for CT scanners in particular. Regionally, the findings of the study are also expected to contribute to the efforts paid in the area of research in the surrounding countries.

Research methods

The study uses a quantitative as well as a qualitative mixed research method in which the data collected is processed statistically to observe, compare and evaluate the averages of the CT doses indicators (CTDI and DLP) in the West Bank governmental hospitals. The results are compared witht he DRLs checklists that were established previously in various countries. Table 1displayed below, shows the names, sites and abbreviations of the CT imaging facilities where data was collected.

Table 1. CT imaging facilities that contain CT scanners in seven cities of the West Bank

Number	Facility name	Abbreviation
1	Hebron Governmental Hospital/Hebron	HGH
2	BeitJala Governmental Hospital/Bethlehem	BGH
3	Palestine Medical Complex/Ramallah	PMC
4	DarwishNazzal Governmental Hospital/Qalqilya	DNGH
5	ThabetThabet Governmental Hospital/Tulkarm	TTGH
6	Jenin Governmental Hospital/Jenin	JGH
7	Rafidia Governmental Hospital/Nablus	RGH

Population and sample selection

The study targets mainly the brain, chest, abdominopelvic, and lumbar spineroutine adult CT examinations that are performed in seven governmental hospitals identified in Table (1) at three months period extending from the first of June 2016 to the first of September 2016. The sample was conducted to collect all the available data (CT examinations) from the CT operator consoles in which a demonstrative sampling design was used. This sample includes all the examinations that stored on the computer system of the medical imaging teamsin HGH, BGH, PMC, TTGH, RGH, DNGH, and JGH, respectively. The age group which was considered in our study ranges from 18 years and above. The other governmental hospitals do not have CT scanners. Other CT-scan examinations or protocols are not included in our study. To facilitate planning of the national dose survey, CT scanners that exist in the governmental imaging facilities were reviewed. Revision involves the manufacturer, scanning technology, and number of detectors (see Table 2).The data was tabulated in an Excel sheet that has been designed up to that time. The data including scanning parameters such as tube voltage (kVp), (mAs), slice thickness & field of view…) and dose descriptors (CTDIvol & DLP) were all considered.

Data Analysis

The data collected was analyzed using an Excel sheet form, in which the mean and standard deviation were calculated for the dose descriptors (CTDI) and (DLP) of the CT examinations. It is important to note here that Syria and Japan have not already established a criterion for lumbar spine examinations. Some governmental hospitals did not have CT scanners, so they were excluded as well.

RESULTS

This section aims at presenting as well as discussing the findings of the study. It first presents the results in sections 3.1 and 3.2.

Results: Count of CT examinations

For this survey, about (2998) CT-examinations were collected. In reference to the type of examination, 47% (n=1417) of the total number is Brain CT, 21% (n=625) is Lumbar spine, 21% (n=624) is Abdominopelvic, and 11% (n=332) is Chest CT examination. Table (3) shows the specific numbers and their percentages of the CT examinations that are processed.

parameter was taken (see Table 4). Different tube voltage (kVp) values were observed at the abdominopelvic and lumbar examinations. The maximum average of tube current (mAs) was recorded for the Lumbar CT-scans (412.2), with highly variable acquisition parameters.

Dose average (dose descriptors) for the most Common four CT-examinations

The average of CT dose descriptors (CTDIvol, and DLP) was calculated, for the target facilities in the study to estimate the doses. The highest (CTDIvol) and (DLP) averages were observed on the brain (CT examinations, and the least for the chest examinations (see Table 5). In reference to the imaging facilities, Table (6) shows the distribution of the examinations among the CT units in the different hospitals. It also shows the percentages of examination types carried out in the local facilities when compared with the percentages of the examinations carried mainly in Australia and Japan,

Averaged CT dose descriptors, (CTDIvol and DLP) Compared with other Countries averages

Results showed that the radiation doses delivered to patients in the CT units among the West Bank governmental hospitals are

Table 2. Characteristics of the CT scanners used in West Bank-Palestine imaging facilities

Number	Hospital Name	CT Scanner (Manufacturer)	Number of Detectors (Slices)	Scanning Technology
1	HGH	Philips	16	Helical
2	BGH	Philips	16	Helical
3	PMC	Philips	128	Helical
4	JGH	GE	4	Helical
5	TTGH	Philips	128	Helical
6	DNGH	Philips	64	Helical
7	RGH*	Philips	16	Helical

*The RGH was non-functional because of technical problems, so no data was collected

Table 3. Arrangement and account of CT examinations according to the data available and type of CT examination

Examination	PMC		HGH		TTGH		BGH		DNGH		JGH		Total	
Types	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Brain	368	12.3%	322	10.7%	307	10.3%	236	7.9%	137	4.4%	47	1.6%	1417	47%
Lumbar spine	183	6%	117	3.9%	132	4.4%	104	3.4%	74	2.6%	15	0.5%	625	21%
Abdominopelvic	173	5.8%	152	5%	119	3.9%	96	3.2%	54	1.8%	30	1%	624	21%
Chest	84	2.8%	58	1.9%	79	2.6%	46	1.5%	37	1.2%	28	0.9%	332	11%
Total	808	26.9%	649	21.6%	637	21.2%	482	16%	302	10%	120	4%	2998	100%

Table 4. The mean or average and (range) of the acquisition parameters that used for four commonest CT-examinations in West Bank-Palestine imaging facilities

Examination	Kvp	mAs	Scan length(mm)
Brain	120	378.26 (599-250)	175.27 (298.9-126)
Chest	120	278.4 (515-131)	370.7 (639-216)
Abdominopelvic	119.87(120-100)	279.24 (737-130)	473.84 (677.5-240)
Lumbar	123.3(140-90)	412.2 (1109-157)	270 (564-165.8)

Table 5. Dose average (dose descriptors) for the most Common four CT-examinations at West Bank- Palestine imaging facilities

Examination	CTDIvol (mGy)		DLP(mGy.cm)	
	Average	SD	Average	SD
Brain	61.8	18.8	1206.6	344.8
Chest	17.5	4	732.6	147.6
Abd-Pelvis	19.3	1.7	960.9	151
Lumbar	30.7	10.3	912.5	287.3

Acquisition parameters

In the six imaging facilities surveyed, helical acquisition geometry was used, and the average of each acquisition

within the range of that amounts from regional and international countries (see Table 7).

Table 6. Average doses (dose descriptors) in CT imaging at west bank-Palestine imaging facilities compared with other averages include (Australia, France, Japan, and Syria, respectively

Examination	West Bank		Australia		France		Japan		Syria	
	CTDI	DLP	CTDI	DLP	CTDI	DLP	CTDI	DLP	CTDI	DLP
Brain	61.8	1206.6	60	1000	65	1050	85	1350	60.7	793
Chest	17.1	732.6	15	450	15	475	15	550	22	520
Abd-Pelvic	19.3	960.6	15	700	17	800	20	1000	24.1	721
Lumbar	30.7	912.5	40	900	45	700	*	*	*	*

Table 7. Averages (Means) of CT dose descriptors (CTDIvol) and (DLP) for each group of CT-scan examinations at West Bank-Palestine imaging facilities

Hospitals	Brain		Chest		Abd-Pelvis		Lumbar	
	CTDI	DLP	CTDI	DLP	CTDI	DLP	CTDI	DLP
HGH	53.9	1003.8	21.3	772	19.7	934.1	23.3	746
BGH	82.2	1787.2	17.5	675.5	18	704.9	32.7	1016.9
PMC	32.3	773.7	18.5	754.7	19.3	1032.8	41.2	1381.1
TTGH	62.1	1089.6	20.9	992.1	21.3	1114.6	23	580
DNGH	58.1	1280.9	12.2	573.1	16.6	896.6	19.8	731.9
JGH	82.1	1304.4	12.5	628.2	20.7	1082.5	44.5	1019
Average	61.8	1206.6	17.1	732.6	19.3	960.9	30.7	912.5
SD	18.8	344.8	4	147.6	1.7	151	10.3	287.3

DISCUSSION

The survey conducted shows variations in the number of the obtained CT examinations. According to the imaging facility examination storage for each individual examination, the researchers observe that 47% of the total number is Brain examination; 21% is Lumbar spine and 21% is Abdominopelvic while 11% is Chest CT examination (see Table 3). The results are normal in the medical imaging departments whereas the Brain CT is considered the most frequent requested examination. The findings are in concord with Moifo's et al. study in Cameron in which the same results were attested (2017). Other differences are spotted in the acquisition parameters (kvp), (mAs), and scanning length. These variations refer to the CT technologist selection or to the protocol itself. In this study the average of the variations in tube voltage (kvp) at the abdominopelvic equals (119.87) whereas it ranges between (120-100). The Lumbar spine examination tube voltage shows an average of (123.3) while it ranges normally between (140-90). This is reasonably practicable as the Lumbar spine requires highly penetrated x-ray photons. Another difference that appears in tube current (mAs) averages, especially in Brain examination where the average reads (378.26) and its range (599-250). This refers to the protocol used and the selection by the technologist, but the maximum value of the range is relatively high for some individual examinations. For the Lumbar Spine the average is (412.2) whereas the range is (1109-157). This is reasonably possible because the lumbar spine imaging usually requires sufficient radiation does to achieve a good image quality. The average (mAs) in Lumber Spine examinations was higher than Brain examinations. The average (CTDIvol) looks lower in Lumber spine examinations. This is due to the use of lower Pitch values in Lumber spine examinations.

In this study, it has been found that the averages of CTDIvol for brain, chest, abdominopelvic and lumbar spine CT-scans equal (61.8 ±18.17 mGy), (17.5 ±3.59 mGy), (19.30 ±5.15mGy) and (30.70 ±12.28 mGy), respectively. And DLP is (1206.60 ±170.47 mGy.cm), (732.60±273.84 mGy.cm), (960.90 ±253.69 mGy.cm), (912.5 ±466.58 mGy.cm), for the same examinations (see Table 5). It has also been observed that the least average of (CTDIvol) is registered for the Brain exam. This is due to the average of (CTDIvol) in PMC that which equals (32.33 mGy). The result is quite low when compared to other hospitals. It also minimizes the average in West Bank medical centers where the average of (CTDIvol) - absent PMC- is (64.46 mGy) while the (DLP) which equals (1206) is higher than all countries except Japan. This refers to the use of wide scan lengths for some of the individual examinations. To compare and contrast the average doses obtained in the West Bank imaging facilities with other countries, see Table 7. In relevance to the Chest CT examinations, the (CTDIvol) averages in our imaging facilities (=17.1) read less than Syria's which equals (22). However, they look higher than the other countries because of the use of relatively high exposure factors particularly (mAs) values. Consequently, the West Bank facilities obtains the highest (DLP) averages among the others due to the use of wide scan lengths especially at TTGH (=20.9) and PMC (=18.5). For the Abdominopelvic CT examinations, the (CTDIvol) averages in our imaging facilities which equal (19.3)and look less than Japan's (=20) and Syria's (=24). The local averages are higher than Australia's (=15) and France's (=17). The variation averages are not, however, very high. This indicates the use of appropriate technical exposure particularly (mAs) values. The averages for DLP in our imaging facilities are mainly less than Japan's while they are higher than the other countries due to the use of wide scan lengths in most of the examinations. In relevance to the lumbar spine CT examinations, the (CTDIvol) averages in our imaging facilities are the least among the available ones. This indicates to the use of the appropriate technical exposure, that is (mAs) values, in particular. The DLP average is the highest among others. It equals (912.5). This can be traced back to the use of wide scan lengths for some of the individual examinations, especially in PMC (=1381.1).

To assess the factor lying behind these averages, a comparison among the West Bank governmental imaging facilities was carried out. It has been found that the highest (CTDIvol) averages are at BGH (=82.2) and JGH (=82.1) done for the brain with minimal variation due to the use of high exposure factor (mAs). As the mean at BGH and JGH is (537.97), it is possible that both centers use high exposure factors (mAs). PMC, however, uses the lower tube current (mAs) between others with a mean of (252.04). This causes high variations in

the (CTDIvol) averages for Brain examinations at West Bank governmental imaging facilities. Therefore. The DLP averages record the highest value at BGH (=1787.2) and the least one at PMC (=773.1) which are both affected by the (CTDIvol) averages. These averages decrease relatively at JGH when compared with BGH because of the potential use of acceptable scan lengths. In relevance to chest examinations, the averages of (CTDIvol) are the highest at TTGH (=20.9). This is due to the use of high tube current (mAs) with a mean of (321.2). However, the least (CTDIvol) averages are taking place at DNGH due to the use of low tube current (mAs) with mean of (186.4). Similarly, the (DLP) averages at TTGH which equals (992.1) look the highest but score the least at DNGH (=573.1)because they are affected by the (CTDIvol). To proceed with the abdominopelvic examinations, the (CTDIvol) averages are the highest at TTGH (=21.3).This is resulted from the use of relatively high tube current (mAs) with mean of (327). The least (CTDIvol) average (=16.6) occurs at DNGH due to the use of lower tube current (mAs) with a mean of (254.09). The highest (DLP) average is spotted at JGH because of the probable use of wide scan lengths and the (CTDIvol) average is close to the TTGH's. The least (DLP) average is observed at BGH due to the use of acceptable scan lengths and its (CTDIvol) average is close to DNGH's.

To end with the lumbar spine examination, the highest average of (CTDIvol) takes place at JGH (=44.5) because of the possible use high tube current (mAs). The lower average of (CTDIvol) is, however, taking place at DNGH (=19.8) as a result of the use of low tube current (mAs) with mean of (296.26). The highest DLP average is observed at PMC (=1381.1) due to the use of wide scan lengths for some of individual examinations with a mean of (247.2 mm), and it had a relatively high (CTDIvol) average that was close to JGH (CTDIvol) average. The least DLP average has revealed at DNGH which has been influenced by the lowest (CTDIvol) average when compared with others, and it has the same average value at TTGH which is affected by lower (CTDIvol) average that looks close to DNGH's despite the use of wide scan lengths. It is important to acknowledge here that one of the main limitations that have already constrained a full understanding of the variables that affected the results is the unavailability of scan parameters for examinations at JGH, according to the CT technologist.

Conclusions and implications

Conclusion

This study concludes that the average of (CTDIvol) for the Brain CT examinations in our facilities is around the averages of other countries except Japan while the DLP average looks close to the other countries except Syria. For the chest examinations, the local average of (CTDIvol) seems in concord with the averages of other countries while the (DLP) average is the highest among the others. In relevance to the abdominopelvic examinations, the average of (CTDIvol) in local medical facilities is similar to the averages of other countries whereas the DLP average seems close to the Japanese one which is higher than other countries'. For the lumbar spine examinations, the average of (CTDIvol) in our local facilities is lower than others while the DLP average comes close to the Australianvalues, but it is higher than French average. All of these variations are due to the use of greatly varied technical factors and protocols that have clear effect on the averages at West Bank-Palestinian imaging facilities. Consequently, all these variations are closely related to the type of examination and the protocol that are applied in each facility, the scanning parameters followed and the acquisition selections followed by the technologist.

Implications for health administrators, medical CT technicians and researchers

To imply for health policymakers at local hospitals, the Palestinian Ministry of Health (PMH) should regard the findings of the studies conducted in the area of medical imaging. A systematic revision of the solid research carried out locally, regionally and internationally will definitely help establish a local diagnostic reference level that can be applied in local medical facilities and used by CT technicians as a CT protocol when dealing with Palestinian patients. There is a gap in the literature, so there is a need to bridge this urgent void. Therefore, researchers should perform some action studies in the field of medical imaging. The research should be periodically systematic. Researchers can collect data at frequent intervals to get a sufficient number of examinations. The researchers whose main interest is fractures within young kids for instance, can collect their data from the annual period extending from June to September. Medical reports show a seasonal rise in fractures among kids due to the long summer holiday students go on right at the end of the schooling year. For more coverage, there is a need for other studies which involve the private hospitals. CT technologists or technicians should not use the same protocols and technical factors for all patients in each individual examination. Certain variables related to the age as well as gender of the patients should be considered when dealing with the dose to be given. The Palestinian medical facilities need to develop the expertise of the CT technologists. Training courses and workshops can be held regionally in the medical centers of the surrounding countries and / or internationally in the countries that manufacture the medical equipment. Such training highlights the dose the technician can give according to the variables of age, gender and the target organ intended to deal with.

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