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The Average Exposure Levels Provided to Neck and Cervical Spine CT Patients at Al-Makassed Hospital and its Worldwide Equivalents

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Abstract: The current study investigates the differences in the average doses used to perform the most common CT examinations of the neck and cervical spine at the Al - Makassed hospital in Jerusalem and its worldwide consistent medical centers regarding the application of the radiation protection optimization principle. The study uses a blended research approach. Thus, it fits into the observational and descriptive studies. It aims to assess the averages of the CT dose descriptors (CTDI and DLP), compare them with those established in various countries, and describe the application of radiation protection principles, especially the optimization principle (ALARA). Studies demonstrate accepted fluctuations in the number of the obtained CT examinations, according to the imaging facility examination storage for each examination, in which 87% of the total number of the cervical spine and (13%) of the Neck. The scan parameters (kvp), (MAs), scan length, and variations refer to the CT engineer's selection or the protocol itself.

Keywords: Radiation dose, Radiation protection principles, Acquisition parameters, Cancer.

INTRODUCTION

Medical imaging procedures have been developed over the last century to develop and process images for different parts of the human body. These modalities involve X-ray, mammography, fluoroscopy, ultrasound, CT, MRI, and PET. Through these modalities, different pathologies have been diagnosed [Martin, C. J. *et al*., 2017]. Computed Tomography (CT) referred to as Computed Tomography (CT) or Axial Computed Tomography (CAT) gives a three-dimensional form (x, y, z). his modality uses specialized x-ray equipment that rotates around the patient to collect views and produce a cross-section image of the human body or for a specific anatomical region. Compared to conventional X-rays CT gives more information and better contrast resolution. However, the danger to a patient is greater than normal X-rays due to increased exposure to ionizing radiation [Kazemi-Bajestani, S.M.R. *et al*., 2016]. The patient radiation dose level is dependent on the parameters " Kilo voltage peak (kVp), milliampere (mA), and time in second (s), and scan length, because of the hazard of ionizing radiation. Limiting the radiation dose in CT through practical optimization is important. (ALARA principle is as low as reasonably achievable). Moreover, it should be performed only the necessary examination and the examination should be justified by the physician these procedures will reduce the unnecessary radiation because it led to cancer for the patient. Low-level radiation should be used to reduce the probability of cancer. Although the risks for any one person are not large, the increasing exposure to radiation in the population may be a public health issue in the future and biological damage effect [Musolino, S.V. *et al*., 1991]. This study aimed to determine the average doses of Al Makassed hospital in CT-scan examinations of Adul which is, which will help in providing initial quantitative standards to enable the radiology professionals to optimize their Practice and achievements, ad to enrich the Palestinian student knowledge about the concepts of optimization tools used all over the world. The most diametric quantities that are used in CT examinations are the CT dose index (CTDIvol), and Dose Length Product (DLP).

Tawfik, A. M. *et al*., 2011 conducted a study to evaluate the Image Quality and Radiation Dose of Dual-Energy CT of the Head and Neck Compared with a Standard 120-kVp Acquisition. overall, thirty-two patients underwent the H&N (tube voltages 80 and Sn140 kVp) and were compared with the last 32 patients who underwent standard SECT (120 kVp) on the same dual-source scanner. WA images from the 2 DE tubes were compared with images obtained with an SE mode. Radiation doses and attenuation measurements of the internal jugular vein, submandibular gland, and sternomastoid and tongue muscles were compared. Objective image noise was compared at 5 anatomic levels. Two blinded readers compared subjective image quality by using 5-point grading scales. They found CTDIvol was 12% lower with DE than with SECT, a difference of 1.5 mGy, ($P < .0001$). Objective noise was not significantly different between DE and SECT at any of the anatomic levels ($P > .05$). No significant differences in

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attenuation measurements were observed between DE and SECT (P> .05). No significant differences in subjective image quality scores were observed between DE and SECT at any of the 5 anatomic levels (P> .05). DE-derived WA images of the H&N are equivalent to standard SE acquisitions and thus can be used for routine diagnostic purposes. Multiple additional image datasets can be obtained with no radiation dose penalty.

Deak, P., Smal, Y. and Kalender, W. in 2010 To determine conversion factors for the new International Commission on Radiological Protection (ICRP) publication 103 recommendations for adult and pediatric patients and to compare the effective doses derived from Monte Carlo calculations with those derived from dose-length product (DLP) for different body regions and computed tomographic (CT) scanning protocols. Effective dose values for the Oak Ridge National Laboratory phantom series, including phantoms for newborns; 1-, 5-, and 10-year-old children; and adults were determined by using Monte Carlo methods for a 64-section multidetector CT scanner. For each phantom, five anatomic regions (head, neck, chest, abdomen, and pelvis) were considered. Monte Carlo simulations were performed for spiral scanning protocols with different voltages. The effective dose was computed by using ICRP publication 60 and publication 103 recommendations. The calculated effective doses were compared with those derived from the DLP by using previously published conversion factors in general, conversion factors determined based on Monte Carlo calculations led to lower values for adults with both ICRP publications. Values up to 33% and 32% lower than previously published data were found for ICRP publication 60 and ICRP publication 103, respectively. For pediatric individuals, effective doses based on the Monte Carlo calculations were higher than those obtained from DLP and previously published conversion factors (e.g., for chest CT scanning in 5-year-old children, an increase of about 76% would be expected). For children, a variation in conversion factors of up to 15% was observed when the tube voltage was varied. For adult individuals, no dependence on voltage was observed. Conversion factors from DLP to effective dose should be specified separately for both sexes and should reflect the new ICRP recommendations. For pediatric patients, new conversion factors specific to the spectrum used should be established [Deak, P.D. *et al*., 2010]. P. C. Shrimpton, M. C. Hillier, M. A. Lewis, and M. Dunn i003 conducted a study to review patient doses from CT examinations in the UK. Overall, Questionnaires were employed to collect scan details both for the standard protocols established at each scanner for 12 common types of CT examination on adults and children, and samples of individual patients. This information was combined with published scanner-specific CT dose index (CTDI) coefficients to estimate values of the standard dose indices CTDIw and CTDIvol for each scan sequence. they found. When compared with a previous UK survey for 1991, wide variations were still apparent between CT centers in the doses for standard protocols. The mean UK doses for adult patients were in general lower by up to 50% than those for 1991, although doses were slightly higher for multi-slice (4+) (MSCT) relative to single slice (SSCT) scanners. Values of CTDIvol for MSCT were broadly similar to European survey data for 2001. The third quartile values of these dose distributions have been used to derive UK national reference doses for examinations on adults (separately for SSCT and MSCT) and children as initial tools for promoting patient protection. The survey has established the PREDICT (Patient Radiation Exposure and Dose in CT) database as a sustainable national resource for monitoring dose trends in CT through the ongoing collation of further survey data.[Shrimpton, P.C. *et al*., 2006]

Foley, S.J. *et al*., 2012 conducted a study on Irish CT diagnostic reference levels (DRLs) by collecting radiation doses for the most commonly performed CT examinations. A pilot study investigated the most frequent CT examinations. 40 CT sites were then asked to complete a survey booklet to allow the recording of CT parameters for each of 9 CT examinations during 12 weeks. Dose data [CT volume index (CTDIvol) and dose–length product (DLP)] on a minimum of 10 average-sized patients in each category were recorded to calculate a mean site CTDIvol and DLP value. The rounded 75th percentile was used to calculate a DRL for each site and the country by compiling all results. Results are compared with international DRL data. They found Data were collected for 3305 patients. 30 sites responded with data for 34 scanners, representing 54% of the national total. All equipment had the multi-slice capability (2–128 slices). DRLs are proposed using CTDIvol (mGy) and DLP (mGy cm) for the CT head (66/58 and 940, respectively), sinuses (16 and 210, respectively), cervical spine (19 and 420, respectively), thorax (9/11 and 390, respectively),

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high high-resolution resolution CT (7 and 280, respectively), CT pulmonary angiography (13 and 430, respectively), multiphase abdomen (13 and 1120, respectively), routine abdomen/pelvis (12 and 600, respectively) and trunk examinations (10/12 and 850, respectively). These values are lower than current DRLs and comparable to other international studies. Wide variations in mean doses are noted across sites. Irish CT DRLs are provided on the most frequently performed CT examinations. The variations in dose between CT departments as well as between identical scanners suggest a large potential for optimization of examinations.

Problem Statement and Significance of Study

Medical imaging using ionizing radiation always has some risk of adverse health effects to the person examined especially on the thyroid gland because it is very sensitive to radiation [Kazemi-Bajestani, S.M.R . *et al*., 2016]. Even though CT is associated with higher radiation exposure than conventional radiography, typical doses are not known. The research is aimed to estimate the radiation dose in CT studies for patients. Also, we observed that there are no practical guidelines have been applied to the CT examinations to become optimized and quality controlled. The health risk to an individual from exposure to radiation from a typical CT scan can be compared to the background levels of radiation. Considering the growing population of people undergoing CT scans. However, the effect of CT radiation dose on public health effects may be significant. Although, considerable debate exists regarding this assumption [McCollough, C.H. *et al*., 2009] to avoid unnecessary CT scans.[Donato, A, 2012].

RESEARCH OBJECTIVES AND INQUIRIES

Significant of Study

The CT examinations are accompanied by higher radiation exposures to patients. During our practice at our imaging facility, in which a greater variability in exposure and technical factors between medical imaging facilities. All of these investigation techniques assist the radiology professionals to optimize their Practices and achievements, hence reducing the patient dose, and will enrich the Palestinian medical imaging specialist's knowledge about the concepts of various optimization tools that are used in the world.

OBJECTIVES OF STUDY

To determine the average of CT dose descriptors (CTDIvol and DLP) that are used for neck and cervical spine CT-scan examinations of adults at Al- Makassed hospital.

To compare local average doses with the published international standards towards investigating our present situation.

METHODOLOGY

RESEARCH DESIGN

This study is a quantitative (observational), descriptive study. It was conducted to describe the dose, by assessment of the CT dose descriptors (CTDI) and (DLP), at Al- Makassed hospital, and their variations from those in the international.

The CT dose descriptors were collected from the cervical spine and neck CT examinations that were hat performed. This was study conducted for one year, from 1 January to 31 December 2018.

Population and Sample Selection

The population of the study targeted cervical spine and neck routine adult CT examinations that were performed in Al- Makassed hospitals for one year period. The study aimed to collect all the cervical neck and spine cases in CT that were conducted in 2018 the data (CT examinations) from the PACS system, in which a Convenience sampling design was used. This means that we take all the examinations that are stored on the computer system by the medical imaging team after the patient has been examined in this hospital. The sample was 222 exams for patients who undergo cervical (n=193) and Neck CT scan (n=29).

INCLUSION CRITERIA

The data was collected from the Al- Makassed hospital in Jerusalem, and only for cervical spine and neck CT adult routine examinations. And the age group considered in our study from 18 years and above. Only non-contrast scans were included in this study for exams with multiple sub-scans

EXCLUSION CRITERIA

The other CT-scan examinations or protocols were not included in our study. Also, the patients under the age group of 18 years were not included in the study. Any examination that includes the neck with another organ in the same sequence was excluded because of the difficulty of dose calculation.

Data Collection

To facilitate the planning of the national dose survey, firstly, the CT scanners that exist in Al-Makassed hospital in Jerusalem and clinical institution demographics were reviewed, in which

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the characteristics of the CT scanners present in this hospital. This involves KVp, mAs, Scan length, Scanning technology, manufacture, and several detectors. which is explained in Tables (2) and (3). To collect the data presented in each CT examination, we used the PACS system, then the data become filled on an Excel sheet that design was needed previously.

DATA ANALYSIS

The data were analyzed by using an Excel sheet form, in which the average and standard deviation of the dose descriptors (CTDI) and (DLP), counting of the CT examinations, and the other acquisition parameters were estimated. Also, the charts that represent the variations of dose descriptors compared with other countries, and between our imaging facilities to determine their differences.

RESULTS AND DISCUSSION

Results

Count of CT Examinations

A total of 222 patients for CT examinations were included in this study counting 13% (n=29) for Neck CT exams, and 87% (n=193) were Cervical CT exams. The survey shows variations in the number of CT examinations obtained from PACS, Table (1), shows the specific number of CT examinations that are available. Also, its counts per type of examination.

Table (1): An arrangement and account of CT examinations according to available data and type of CT examination

Examination/hospital	AL- Makassed hospital
C-spine	193
Neck	29
Total	222

For the counting of examinations and Their classifications according to gender (male or female), in which 45% females, and 55% males for the Neck examinations, while 60% males and 40% females for the Cervical spine examinations. Figure (1).

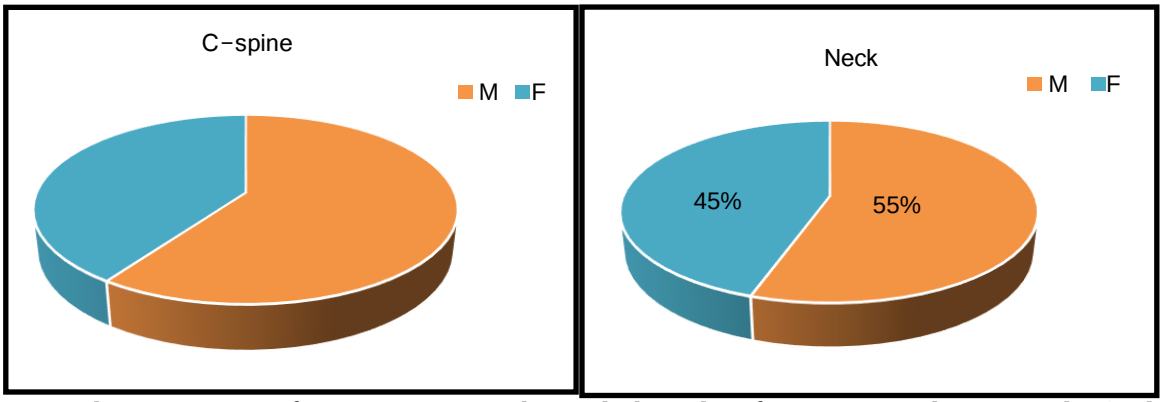

Figure 1: the percentages of examinations number and Their classifications according to gender (male or female)

Acquisition Parameters

The imaging facility that included, helical acquisition geometry was used, and the average of each acquisition parameter was taken. In table (2), the different tube voltage (kVp) values were observed during the cervical spine and Neck examinations. The maximum average of tube current (mAs) was recorded for the Cervical CT scans at an average of (300), with highly variable acquisition parameters.

Table 2: The average of the Acquisition parameters that were used at AL- Makassed in Jerusalem

Examination	Kvp	mAs	Scan length(mm)
C-spine	140	300	251
Neck	120	300	251

Average Doses (Dose Descriptors) for Cervical Spine and Neck CT- Examinations at Al-Makassed Hospital Imaging Facility

The average of CT dose descriptors (CTDIvol, and DLP) was determined, that are used in all the participating facilities in the study to estimate the doses, the (CTDIvol) and (DLP) averages were observed on the Cervical spine and Neck CT

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examinations in Table (3).

Table 3: The averages (Means) of CT dose descriptors (CTDIvol) and (DLP) for each group of CT-scan examinations at AL- Makassed hospital in Jerusalem

Examinations	Average. CTDIvol (mGy)	Average. DLP (mGy.cm)
Neck	14.57(2.59±)	442.66(156.20±)
C-spine	21.66(1.48±)	597.04(100.1±)

The average of CT dose descriptors (CTDIvol, and DLP), that are present in all the participating facilities in the study is demonstrated by the following Figures (2 & 3).

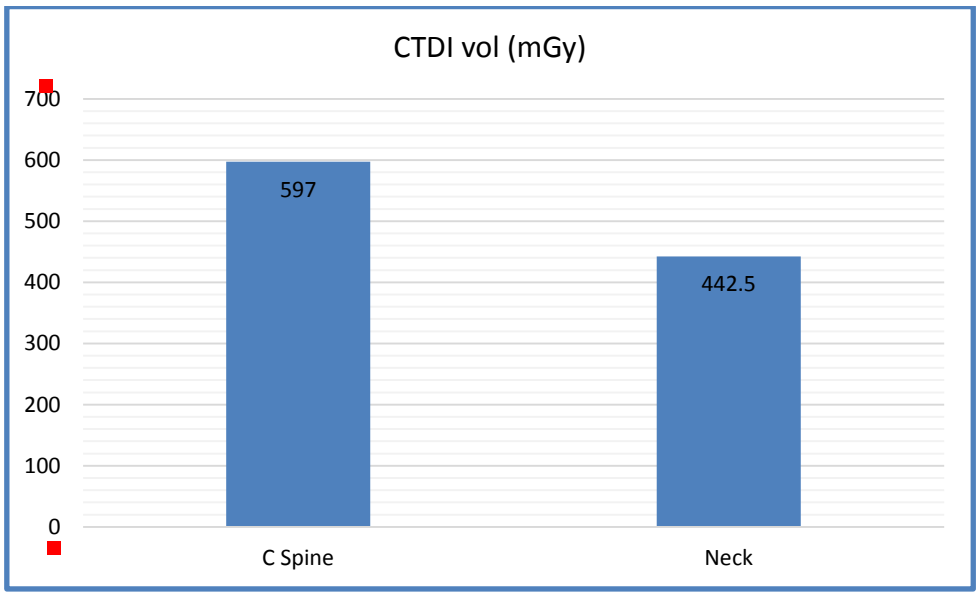

Figure 2: the average CT dose descriptor (CTDIvol) at AL-Makassed hospital for the (Cervical spine, Neck) CT examinations

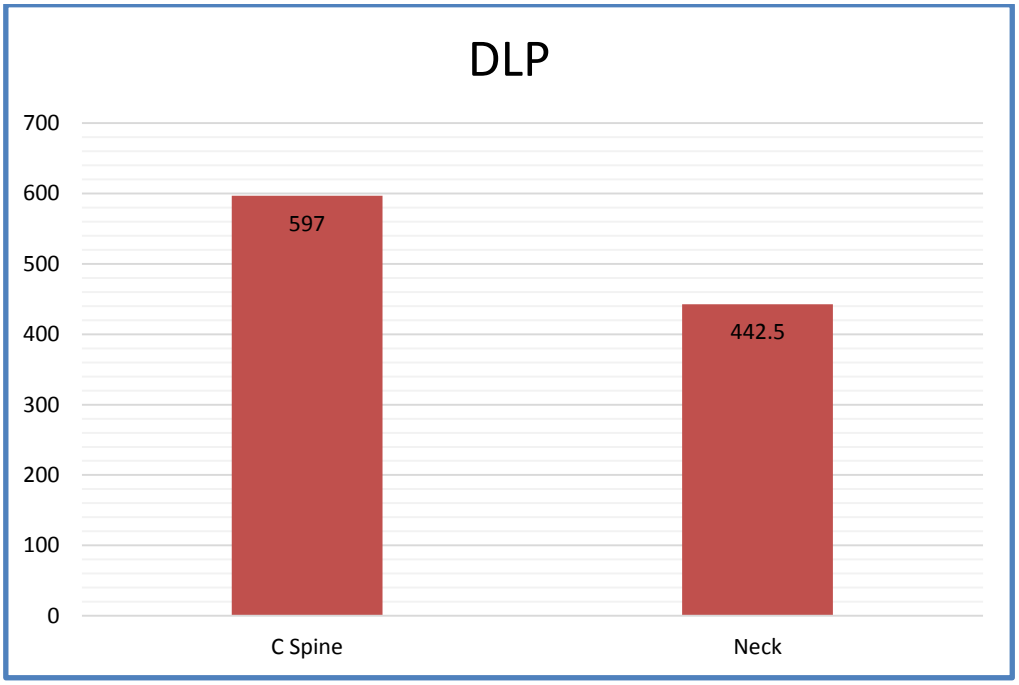

Figure 3: the average CT dose descriptor (CTDIvol) at AL-Makassed hospital for the (Cervical spine, Neck) CT examinations

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Averaged CT Dose Descriptors, (CTDIVOL and DLP) Compared with other Countries Averages

This study aimed to assess the variations of our average doses (dose descriptors), from the others that are published all over the world, toward the application of the optimization principle, a comparison among these values was performed, the countries are Ireland, Switzerland, USA, and Australia, respectively, in which its averages were achieved in a different period, but the Neck examination was not established in Ireland and considered as an exclusion examination in the study, Table (4) demonstrates the differences between the compared average doses.

This table will help to understand more about the variations between the averages Dose descriptors in our study and other studies in other countries. The averages of dose descriptor (CTDIvol) differences between AL-Makassed hospitals for the Cervical spine and Neck examinations and other countries include (Ireland, Switzerland, the USA, and Australia, respectively) Figure (4).

Table 4: Average doses (dose descriptors) in CT imaging at AL-Makassed hospital compared with other averages

	Our study averages		**Ireland 2015** [Thomas, P. *et al*., 2015]		**Switzerland 2015** [Thomas, P. *et al*., 2015]		**USA 2013** [Huda, W. *et al*., 2013]		**Australia 2015**[Thomas , P. *et al*., 2015]	
Examination	CTDIvol	DLP	CTDI vol	DLPlds	CTDI vol	DLP	CTDI vol	DLP	CTDI vol	DLP
C-spine	21.66 (1.48±)	597.04(100.1±)	19	420	30	600	30	663	30	600
Neck	14.7(2.59±)	442.66(156.20)	****	****	23.6	513	24.3	706	23.6	513

*The country that did not establish an average Neck examination

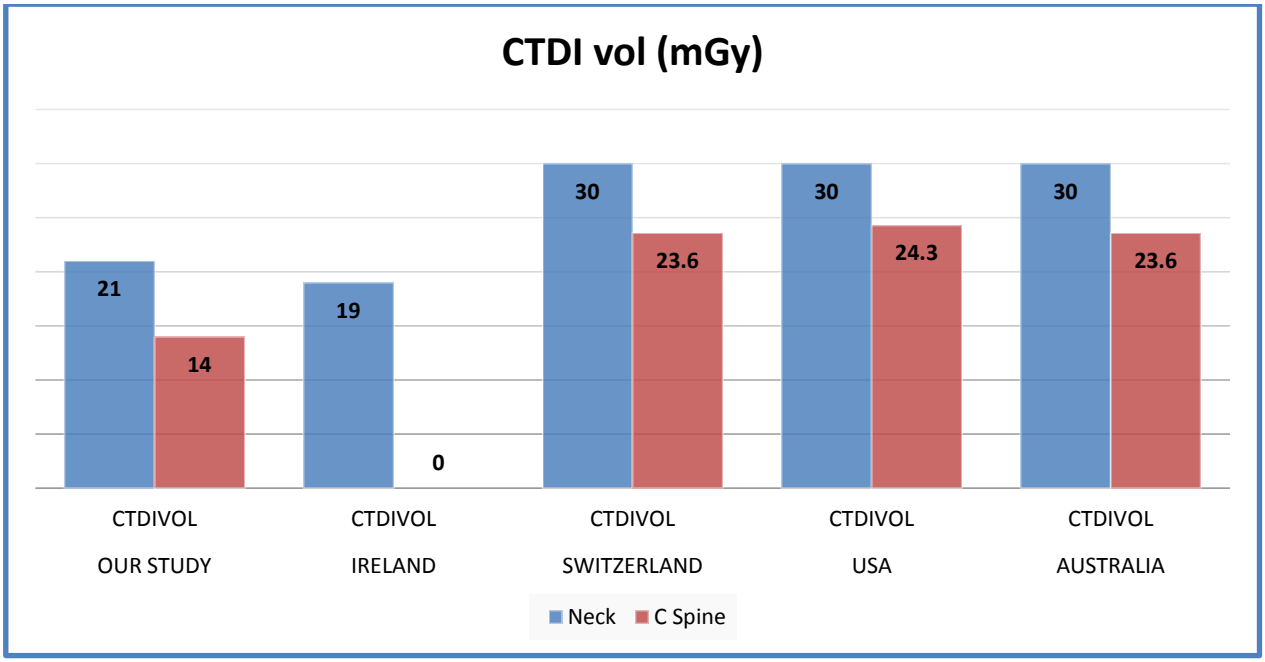

Figure 4: The CT averages of dose descriptor (CTDIvol) differences between AL-Makassed hospitals for the cervical spine, neck, and the other countries

The averages of dose descriptor (DLP) differences between AL-Makassed hospitals for the Cervical spine and Neck examinations and other countries include (Ireland, Switzerland, the USA, and Australia, respectively) Figure (5).

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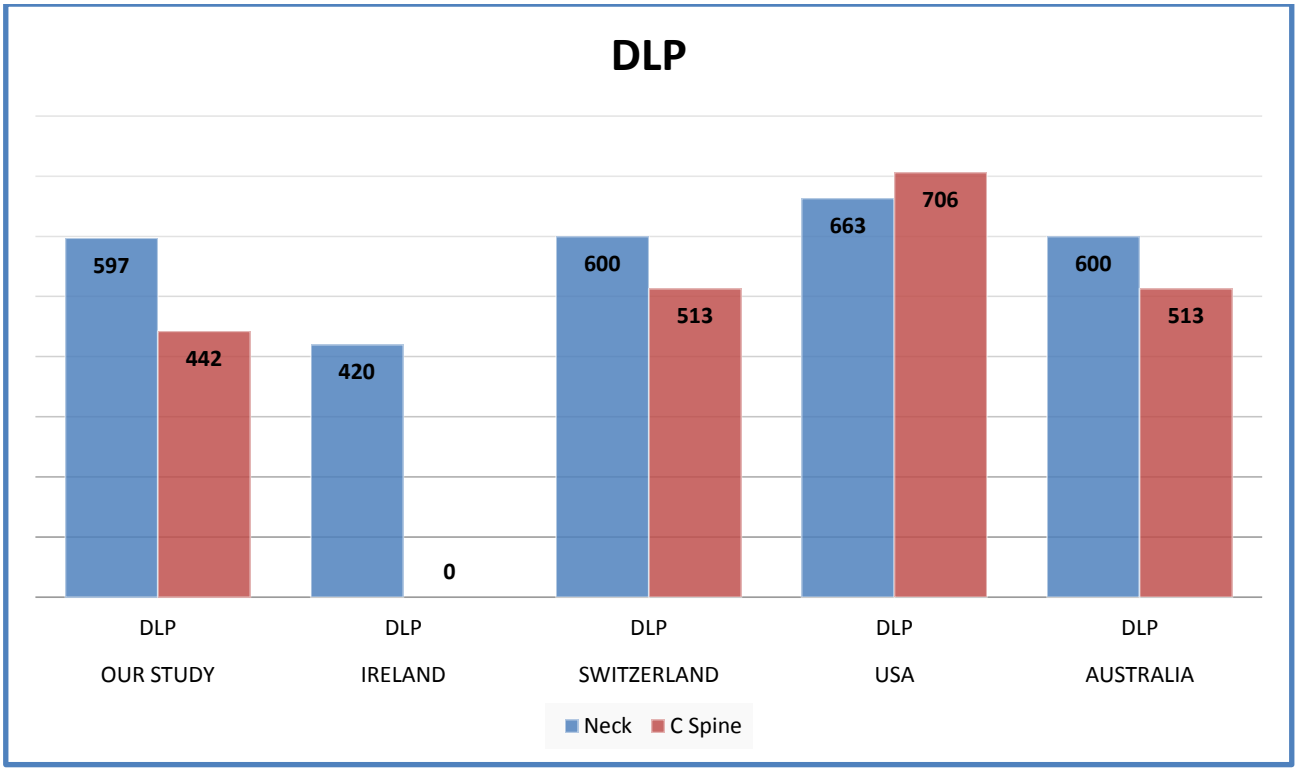

Figure 5: The CT averages of dose descriptor (CTDIvol) differences between AL-Makassed hospitals for the cervical spine, Neck, and the other countries

Cervical Spine CT Examination

The average CT dose descriptor (CTDIvol) of cervical spine examination in Ireland was less than our facility (19 mGy) and our facility (21.66(1.48±) mGy) less than USA, Switzerland, and Australia (30 mGy). (Figure 6).

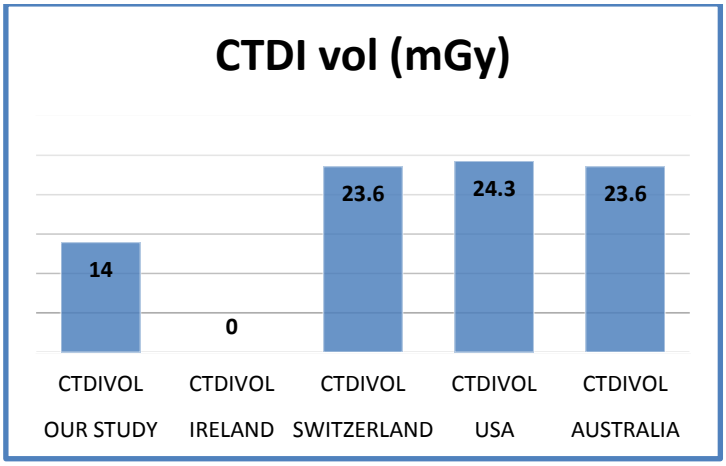

Figure 6: the average CT dose descriptor (CTDIvol) at our facilities was lower than in Switzerland, the USA, and Australia, but higher than in Ireland for the cervical spine examination

Neck Examination

The average dose descriptor (CTDIvol) for the Neck examinations at our facilities was (14.7(2.59±) mGy), which is lower than the other countries, Figure (7).

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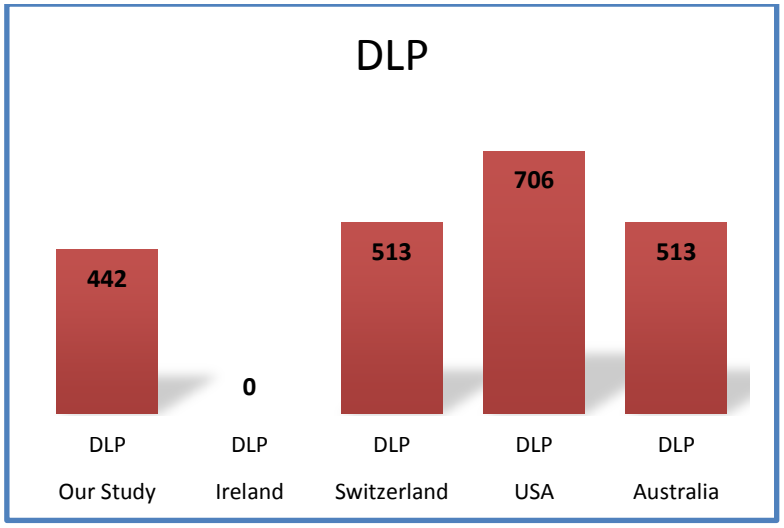

Figure 7: the average CT dose descriptor (DLP) at our facilities was the least among the others for the Neck examination

The (DLP) average is the lowest among the other countries, at approximately (442.66(156.20±) mGy.cm), Figure (8).

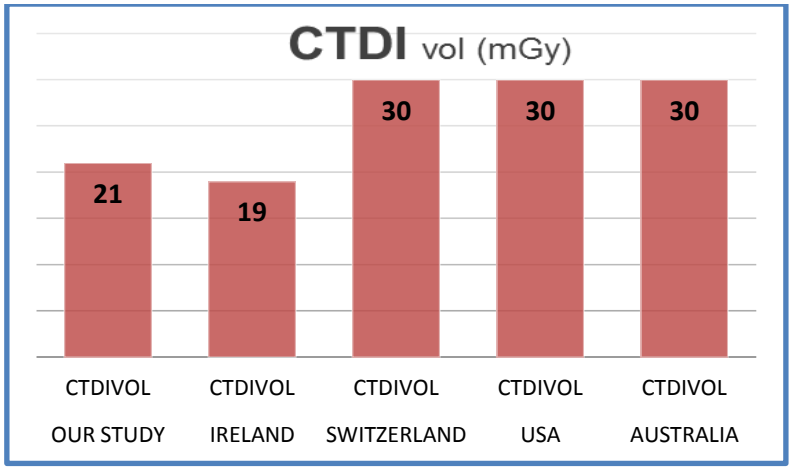

Figure 8: the average CT dose descriptor (CTDIvol) at our facilities was the least among the others for the Neck examination

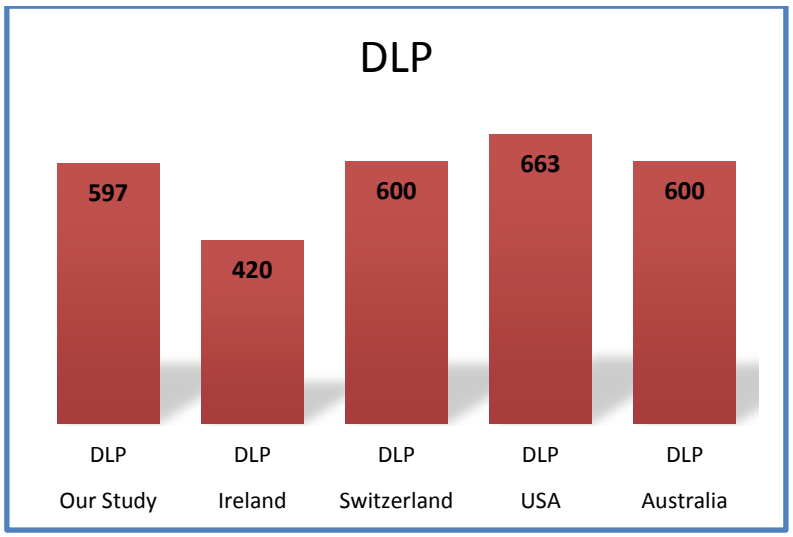

Figure 9: the average CT dose descriptor (DLP) at our facilities was the least among the others for the Neck examination

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DISCUSSION

We fulfill this descriptive study to review and evaluate the average doses at the AL- Makassed Hospital in Jerusalem in CT imaging facilities for adult routine CT scans examinations of the cervical spine and neck. The study showed alternations in the number of the obtained CT examinations. According to the imaging facility examination storage for each examination, as we observe, 87% of the total number were Cervical spine and 13% Neck. This is normal actually because the cervical is a more frequent request for examinations in the medical imaging department than the Neck examination. Other differences were found in the acquisition parameters (kvp), (mAs), and scanning length), these variations, refer to the CT technologist selection or to the protocol itself. In our study, the tube voltage (kvp) at the cervical spine examination was (140), while at the Neck examination the tube voltage was (120), this is reasonably practicable, in which the Cervical spine requires highly penetrated x-ray photons. However, the tube current (mAs) is the same for both Cervical spine and Neck examinations which were (300). Any alternation in this parameter will affect the patient's dose. The average CTDI for cervical in our facility in 2018 is 21.66(1.48±) mGy.cm we compared it with four countries, The CTDI in Ireland in 2015 was 19 mGy.cm which is lower than our results, Switzerland in 2015 was 30 mGy.com which is higher compared with our results, But the USA in 2013 the average CTDI for cervical was the same of Switzerland which it is 30 mGy.com, The last country was Australia the average of CTDI in 2015 was also 30 mGy.com which is higher than our results.

The DLP in our facility was (597.04(100.1±)) but in comparison to the previous studies, Ireland was (420) which is lower than our result (42%), in Switzerland we found that the DLP was 600 which is almost near to our facility (0.01%), and the study in the USA was also near to our result which is (663) but we are less than 10% compared with the USA, finally, in Australia, the DLP was 600 which is the same as Switzerland (0.01%), all the values for DLP were near to each other, so the main reason for these results were the parameters (Kvp, mAs) that were almost the same of these countries then we found that the results in DLP of our study are somewhat similar to those of international studies.

The average CTDI for Neck examination in our facility was 14.7(2.59±) mGy.cm, we compared this value with the same countries explained previously, Switzerland was 23.6 mGy.cm which is higher than our result of 48%, the USA value for CTDI was 24.3 which was higher than our result in 40% the last country that we compared with it was Australia which was the CTDI 23.6 was the same value Switzerland which is the percentage was 48% higher than our result.

The average of DLP also for Neck examination in our Result was 442.66(156.20±), this value was compared with Switzerland the DLP value is 513 which is higher than our result (14%), the USA Value is 706 which is higher than our result 37% and lastly the DLP for Australia was the same of Switzerland which is 513 and the percentage was 14%. All CTDI and DLP values in Al– Makassed hospital were accepted and it within normal levels comparable with the countries.

CONCLUSION

This study concluded with the following results, for the comparison of the average doses from our imaging facilities and the other countries, the average of (CTDIvol) for cervical spine CT examinations in our facility was around the average of Ireland but higher for the other countries, in while the (DLP) average was near to the other countries except for Ireland, for the neck examinations in our facility the average of (CTDIvol) was lower than the other countries, while the (DLP) average was near to the other countries except for the USA

RECOMMENDATIONS

The technologists should not use the same protocols and parameters for all patients.

A ministry of Health should review the results of this study that will help to establishment of diagnostic reference levels.

Should undergo training courses to develop their expertise.

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