CT Patient Radiation Dose Reduction and Verification Using Single-Unit Imaging Techniques and OSL Technology

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1- Abstract

Radiation doses received by patients who undergo CT examinations has become a subject of considerable interest. Adult effective doses for head CT examinations are of the order of 1to2 mSv, for a single body examinations, patient doses are typically between 4 and 6 mSv. These doses are considered to be relatively high in comparison to most other types of radiological examinations that uses ionizing radiation. Patient CT doses may also be compared with natural background (3 $mSv.year^{-1}$), dose limits to members of the public (1 $mSv.year^{-1}$), and the maximum allowable highest level of occupational exposure, is 20 $mSv.year^{-1}$. [1]The advent of multi-slice technology will serve to increase CT utilization, as well as individual doses for any given examination.

Radiologists are responsible for medical radiation doses of their patients, and it is imperative that they understand the relationship between patient radiation dose and image quality.This research project has presents the collected Patients CT radiation; Lens, Deep and Shallow absorbed radiation dose rates using the "Optical Simulated Lumincint" OSL-badges. Surveillance was carried out for a 24 patients at the Hadba Gahdra Hospital in Tripoli. Upon reviewing all tabulated of the collected data, it can be clearly seen as lowered the scan number the measured doses has dropped accordingly. It was noted that the required image information were enough for medical doctors to get the required diagnosis. The collected dose rates for the three patients that were scanned four times and also these data were depicted in a number, it can be seen that the absorbed dose were very high and ranged between 332 to 413 micro-Siveriet for the deep radiation doses.

Also the collected dose rates for the three patients that were scanned three times, it can be seen that the absorbed dose were very high and ranged between 167 to 310 micro-Siveriet for the deep radiation doses. The collected dose for the patients that were scanned three times, it can be seen that the absorbed dose were lowered tremendously and ranged between 22to 77micro-Siveriet for the deep radiation doses.
In conclusion, it is clear that CT scans causes high radiation exposure which is about ten times single chest x-ray. Also, it is clear that the more CT images to be taken the more the exposure radiation doses to the patient. Therefore, there should be consensus among the medical doctors and CT operators and radiation protection specialists of lowering the medical radiation exposures to patient as low as reasonably achievable according to the rules and regulations set by ICRP61. A number of recommendations were introduced to TMC hospital administration that might be put into practice in order to lower CT patient radiation doses.

2- Introduction

Computerized Axial Tomography CAT or also widely known as CT is the acronym for the modern medical device that uses X-rays to obtain a stereoscopic image of the human body instead of traditional X-rays that provide simple information about the skeletal structure of humans and some body organs. [1] CT imaging using X-ray technology, and it's development which depends on the rapid development of the computer advancements and it's process speed. Using CT devices, the doctor can examine and diagnose the human body accurately so that it can look at the inside of human body as a component of thin slices to identify the disease, place and size accurately and at high speed.[2]

The a patient is photographed using the patient's CT scan several times, and for the purpose of obtaining the appropriate diagnosis, the patient is exposed to a number of times for radiation exposure at the same time also exposing the CT operators and the medical doctors. [3] Through pure radiation tests which can be performed a number of times so that the radiation scan is reduced and access to the proper and the required medical diagnosis. In this regard, it is essential to establish a basic reference for radiation workers to perform the required tests, not routine, which indicates a defined working parameters for understanding what is required.

This reduction can be verified by using Optical Simulated Lumincense "OSL" badge for measuring patient radiation doses before and after manipulation of reducing radiation exposure time There is an urgent need to reduce the number of radiation scan times, without minimizing the process of diagnosis.Most of the research that has been carried out on this subject, was to stimulate the focuses on how to reduce radiation dose from the computational point of reducing the amount of patient dose, but not taken into account the number of radiation exposure times and how to use special techniques which will reduce patient exposure time. [4]

3- Experimental Procedures:

3.1 - OSL - The dosimeter of the future

The OSL dosimetry (Optically Stimulated Luminescence) is a method that has established itself in the whole-body dosimetry, and it represents a breakthrough in the measurement of the personal dose equivalent $H_p(10)$. It is ideal for the evaluation and surveillance of the personal dose by photon radiation. With the measuring method by means of the optical stimulated luminescence, an energy range of 16 keV to 7 MeV can be covered, The OSL dosimeter used in this research project consist of a light-tight dosimeter sheath of which the upper shell and the lower shell are ultrasonically welded, the detector card being located in the middle of the two shells. Two detectors based on Beryllium Oxide Ceramic are attached to the detector card. Due to their positive dosimetric property to record radiation of different energy in all tissues with only small deviations (linearity over a wide energy range and tissue equivalence), the beryllium oxide detectors are particularly suitable for the whole-body dosimetry, In order to avoid dose manipulations and contamination by dust and water, all OSL dosimeters are supplied in a blister package. The OSL dosimeter is attached to a belt clip. In addition, a cassette in several colors is also available for selection. The OSL dosimeter is an official personal dosimeter approved by virtue of its construction by the Physikalisch-Technische Bundesanstalt (PTB).The principle of optically stimulated luminescence (OSL) is similar to the principle of the thermally stimulated luminescence (TLD).

Energy in the form of ionizing radiation hits the BeO detector and is stored by lifting electrons to higher energy levels.

In this process, electrons are caught in so-called electric traps until an excitation by light occurs again so that the electrons fall back to a lower energetic basic level. In this manner, the detector releases the stored energy in the form of light, i.e., it is stimulated to emit light. The light output measured with photomultipliers is a measure unit for the dose, Unlike in the thermally stimulated luminescence, the excitation in the optically stimulated luminescence is achieved by light and not by heat.

The OSL is issued by the monitoring service in a blister package for a certain wearing period (usually for one month or for a maximum of three months). The front side of the package is covered with a label on which the dosimeter ID, the operation number, the monitoring period and the provisional personal assignment are printed. This label is designed exclusively for personal dosimeter data management, it can be overwritten with a new label and stacked on it. However, the additional label may not overtop the front side of the package, and it must be made of paper or chlorinated hydrocarbon polymers (e.g., polyethylene or polypropylene). The total thickness of the label and the optional carry bag must not exceed 0.2 mm. The dosimeter must be positioned towards the expected radiation source in such a way that the radiation optimally reaches the probe level perpendicularly from the front, however, always maintaining an incidence angle of +60 to -60 degrees.

The dosimeter is suitable for use at ambient temperatures of 10° C to +40° C and a relative humidity of 10% to 90%. It should not be exposed to direct sunlight radiation over 1000 W / m². If necessary, the blister packaging can be cleaned with a damp cloth.

3.2- OSL Badges positioning on patients

The OSL dosimeter should be worn on a part of the body most likely to receive exposure - usually on the trunk, in the chest area or hip area. If the radiation Worker uses a lead apron, the dosimeter must be worn under the lead apron, or for comparison purposes one badge could be used under the apron and one over it. In this research project the main interest was to measure the CT-patient doses during routine CT examinations requested by examining radiologist and medical specialists. Two OSL badges were used for each patient and were positioned Undernet the patient main organ of the examination request. The collected data for 24 patients were followed and registered in Table1 It has to be noted the researcher was the technical operator of the used CT at the Hadba Ghdara hospital in Tripoli.

The researcher discussed the outline of the research project in order to lower the patient doses by number of the requested scans without affecting the image quality or medical information that has been requested by the specialists for that particular organ. As it can be seen from the data collected for all 24 patients, the number of scans was reduced from four scans to each patient which contributes higher doses to only one scan for each patient with reduced the absorbed radiation doses to each patient while no lose of the medical information requested.

4- Data presentation of the study

Table 2 presents all the collected dose rates for twenty-four patients using the four types of imaging criteria's. The researcher is a CT engineer and operator at the Hospital has been work for a number of years he has noticed that the routine imaging for all patient by carrying four images on the same patient for the same diagnosis.

The researcher discussed the imaging criteria with the medical doctors and it's implication on it's unnecessary radiation doses to the patients. They all agreed to lowers the number of the number of the routine scans on condition that it will not lower the image quality and the medical outcome from the intended diagnosis. Radiation doses received by patients who undergo CT examinations has become a subject of considerable interest. Adult effective doses for head CT examinations are of the order of 1 to 2 mSv, for a single body examinations, patient doses are typically between 4 and 6 mSv. These doses are considered to be relatively high in comparison to most other types of radiological examinations that uses ionizing radiation. Patient CT doses may also be compared with natural background (3 mSv/year), dose limits to members of the public (1 mSv/year), and the maximum allowable highest level of occupational exposure, is 20 mSv/year. [5] The advent of multi-slice technology will serve to increase CT utilization, as well as individual doses for any given examination. Radiologists are responsible for medical radiation doses of their patients, and it is imperative that they understand the relationship between radiation dose and image quality. Table1 Presents the collected Patients CT radiation; Lens, Deep and Shallow absorbed radiation dose rates using the OSL-badges. Surveillance was carried out for a 24 patients at the Hadba Gahdra Hospital. The following Table presents all the collected data; deep, shallow and lens doses for the twenty four patients using different number of scans.

It can be clearly seen as lowered the scan number the measured doses has dropped accordingly. It was noted that the required image information were enough for medical doctors to get the required diagnosis.

Table 1 Presents the collected all Patients CT radiation; Lens, Deep and Shallow absorbed radiation dose rates using the OSL-badges.

Summation	DEEP DOSE	Summation	LENS DOSE	Summation	SHALLOW DOSE	No. Scans	Age	Patient Code
	384.32		384.32		320.27	4	66	1
364.747	445.17	364.747	345.17	315.605	310.94	4		1
	413.33		413.33		390.78	4	40	2
399.295	385.26	399.295	385.26	378.985	367.19	4		2
	332.4		332.4		315.7	4	36	3
349.79	367.18	349.79	367.18	336.96	358.22	4		3
	288.77		288.77		244.33	3	55	4
262.6	236.6	262.685	236.6	234.515	224.7	3		4
	249.3		249.3		236.83	3	67	5
247.5	245.7	247.5	245.7	240.015	243.2	3		5
	310.67		310.67		307.70	3	52	6
265.635	220.6	265.635	220.6	261.7	215.7	3		6
	240.5		240.5		238.7	3	30	7
	220.4	230.45	220.4	228.7	218.7	3		7
	197.7		197.7		195.2	3	40	8
212.58	227.58	212.58	227.58	211.2	227.20	3		8
	220		220		190	3	75	9
218.5	217	218.5	217	185	198	3		9
	167.7		167.7		160.9	3	49	10
155.65	143.6	155.65	143.6	149.35	137.8	3		10
	242.7		242.7		238.2	3	47	11
181.15	219.6	181.15	219.6	226.625	215.05	3		11
	113.7		113.7		112.9	2	34	12
111.735	109.77	111.735	109.77	107.91	102.92	2		12
	122.7		122.7		118	2	21	13
124	125.3	124	125.3	120.35	122.7	2		13
	119.6		119.6		118.3	2	27	14
120.5	121.4	120.5	121.4	119.45	120.6	2		14
	115.6		115.6		113.2	2	43	15
120.15	124.7	120.15	124.7	118.75	124.3	2		15
	127.6		127.6		125.9	2	69	16
124.65	121.7	124.65	121.7	123.4	120.9	2		16
	28.22		28.22		26.81	1	31	17
27.2	26.18	27.2	26.18	25.84	24.87	1		17
	14.88		14.88		13.27	1	31	18
14.86	14.84	14.86	14.84	13.155	13.04	1		18
	77.43		77.43		74.03	1	52	19
77.235	77.04	77.235	77.04	75.475	76.92	1		19
	36.67		36.67		34.84	1	49	20
38.33	39.99	38.33	39.99	36.175	37.51	1		20
	22.65		22.65		20.11	1	53	21
21.885	21.12	21.885	21.12	15.41	10.71	1		21
	45.8		45.8		43.3	1	77	22
65.75	85.7	65.75	85.7	63.45	83.6	1		22
	30.37		30.37		30.7	1	82	23
60.245	90.12	60.245	90.12	58.99	87.28	1		23
	27.95		27.95		27.20	1	23	24
49.49	71.03	49.49	71.03	48.85	70.5	1		24

Table 2 Present the summation of all the collected radiation doses deep, lens and shallow for all patients that

DEEP DOSE	LENS DOSE	SHALLOW DOSE	No. Scans	Patient code
384.32	384.32	320.27	4	1
445.17	345.17	310.94	4	1
413.33	413.33	390.78	4	2
385.26	385.26	367.19	4	2
332.40	332.40	315.70	4	3
367.18	367.18	358.22	4	3
288.77	288.77	244.33	3	4
236.60	236.60	224.70	3	4
249.31	249.30	236.83	3	5
245.70	245.70	243.20	3	5
310.67	310.67	307.70	3	6
220.60	220.60	215.71	3	6
240.51	240.50	238.71	3	7
220.40	220.40	218.70	3	7
197.70	197.70	195.20	3	8
227.58	227.58	227.20	3	8
220.00	220.00	190.00	3	9
217.00	217.00	198.00	3	9
167.70	167.70	160.91	3	10
143.60	143.60	137.82	3	10
242.70	242.70	238.21	3	11
219.60	219.60	215.05	3	11
113.71	113.70	112.91	2	12
109.77	109.77	102.92	2	12
122.70	122.71	118.10	2	13
125.31	125.31	122.70	2	13
119.61	119.62	118.30	2	14
121.40	121.41	120.60	2	14
115.60	115.61	113.20	2	15
124.72	124.72	124.30	2	15
127.60	127.61	125.90	2	16
121.72	121.71	120.90	2	16
28.22	28.22	26.81	1	17
26.18	26.18	24.87	1	17
14.88	14.88	13.27	1	18
14.84	14.84	13.04	1	18
77.43	77.43	74.03	1	19
77.04	77.04	76.92	1	19
36.67	36.67	34.84	1	20
39.99	39.99	37.51	1	20
22.65	22.65	20.11	1	21
21.12	21.12	10.71	1	21
45.81	45.80	43.30	1	22
85.71	85.70	83.60	1	22
30.37	30.37	30.70	1	23
90.12	90.12	87.28	1	23
27.95	27.95	27.20	1	24
71.03	71.03	70.50	1	24

5- Data analysis for the patients that were scanned four times.

Table 3 Present the collected dose rates for the three patients that were scanned four times and also these data were depicted in Figure 1, it can be seen that the absorbed dose were very high and ranged between 332 to 413 micro-Siveriet for the deep radiation doses.

Table 3 Presents the collected dose rates for four times scans.

DEEP DOSE	LENS DOSE	SHALLOW DOSE	Case No.
384.32	384.32	320.27	1
413.33	413.33	390.78	2
332.40	332.40	315.70	3

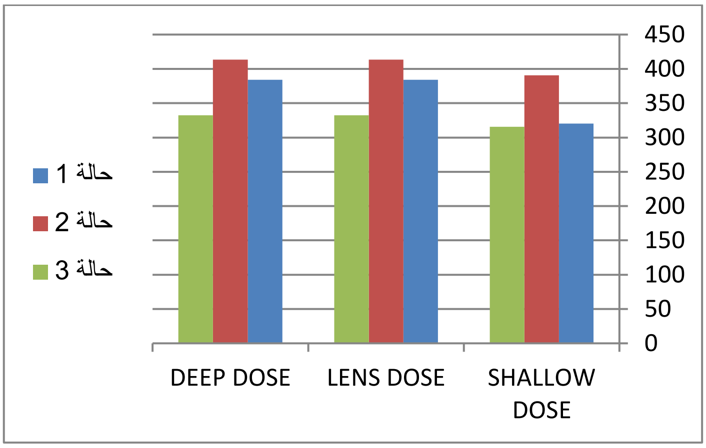

Figure .1 Shows the radiation doses values for four times scans.

From the data presented in Table 4.3 and Graph 1, it can be seen that dose rates were compatible and all radiation absorbed doses were very high and was in range of 30 to 400 micro-Siveriet for deep, lens and shallow doses.

6- Data analysis for the patients that were scanned three times.

Table 4 Present the collected dose rates for the three patients that were scanned three times and also these data were depicted in Figure 4.2, it can be seen that the absorbed dose were very high and ranged between 167 to 310 micro-Siveriet for the deep radiation doses.

Table 4 Present the collected dose rates for four times scans.

DEEP DOSE	LENS DOSE	SHALLOW DOSE	Case No.
288.77	288.77	244.33	4
249.30	249.31	236.83	5
310.67	310.67	307.70	6
240.50	240.50	238.70	7
197.70	197.70	195.20	8
220.00	220.00	190.00	9
167.70	167.71	160.90	10
242.70	242.70	238.20	11

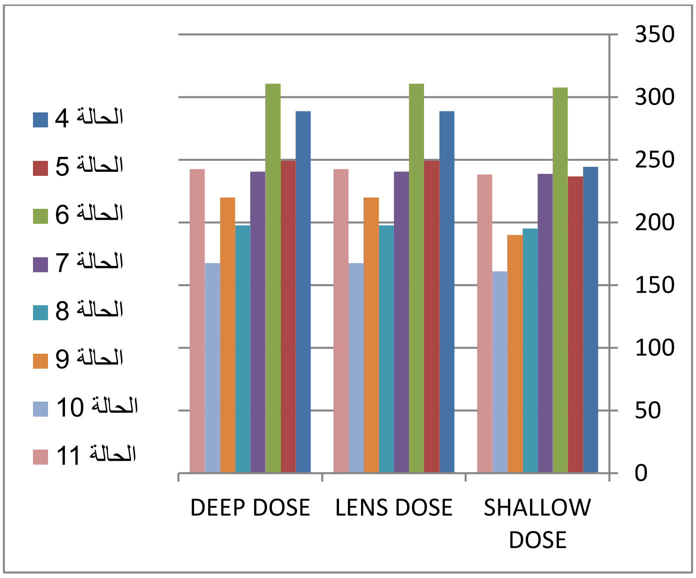

Figure 2 Shows the radiation doses values for three times scans.

7- Data analysis for the patients that were scanned two times.

Table 5 Present the collected dose rates for the two patients that were scanned three times and also these data were depicted in Figure 4.3 , it can be seen that the absorbed dose were very high and ranged between 167 to 310 micro-Siveriet for the deep radiation doses.

Table 5 Present the collected dose rates for two times scans.

DEEP DOSE	LENS DOSE	SHALLOW DOSE	No. Scans
113.7	113.7	112.9	12
122.7	122.7	118	13
119.6	119.6	118.3	14
115.6	115.6	113.2	15
127.6	127.6	125.9	16

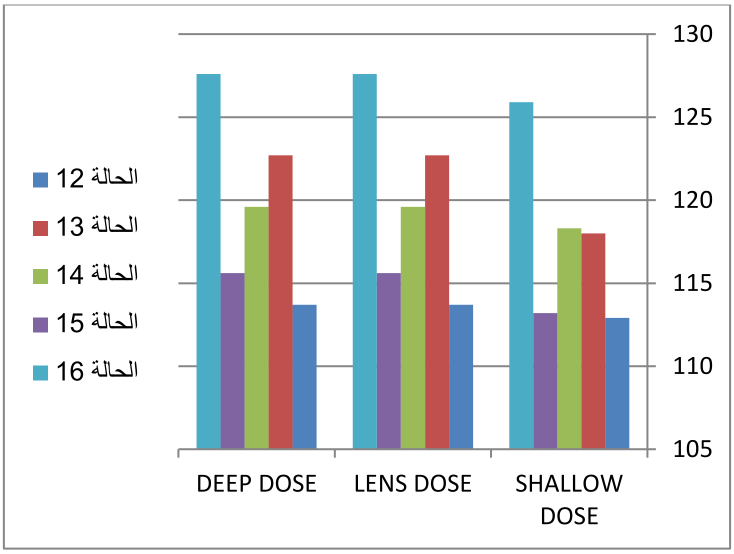

Figure 3 Shows the radiation doses values for two times scans.

8- Data analysis for the patients that were scanned one time.

Table 6 Present the collected dose rates for the two patients that were scanned three times and also these data were depicted in Figure 4.3 , it can be seen that the absorbed dose were lowered tremendously and ranged between 22 to 77 micro-Siveriet for the deep radiation doses.

Table 6 Present the collected dose rates for two times scans.

DEEP DOSE	LENS DOSE	SHALLOW DOSE	No. Scans
28.22	28.22	26.81	17
14.88	14.88	13.27	18
77.43	77.43	74.03	19
36.67	36.67	34.84	20
22.65	22.65	20.11	21
45.8	45.8	43.3	22
30.37	30.37	30.7	23
27.95	27.95	27.20	24

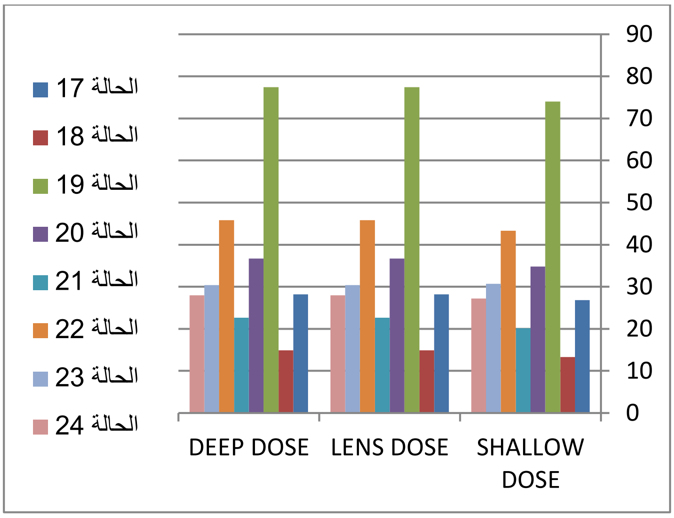

Figure 4 Shows the radiation doses values for one time scans.

Data analysis for the average radiation patients dose for the four types of scanning times.

Table 6 Present the average collected dose rates for the four types of patients scanning these data were depicted in Figure 4 , it can be seen that the absorbed dose were lowered tremendously when lowering the times of scanning and as it can seen. The values for the deep radiation doses ranged between 43 to370micro-Siveriet.

Table7 Present the collected dose rates for the four times of scans.

DEEP DOSE	LENS DOSE	SHALLOW DOSE	No. Scans
370.8	370.8	342.133	4
270.76	270.76	217.087	3
120.186	120.186	117.94	2
43.6875	43.6875	42.28	1

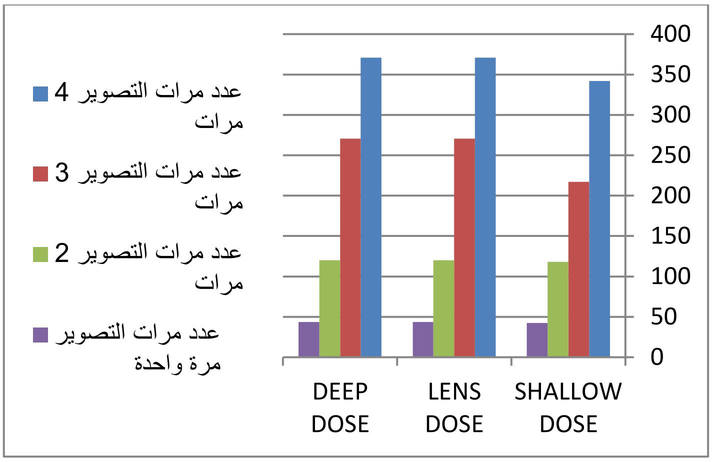

Figure 5 Shows the average radiation doses values for the four times scans.

9- Result and Discussion

The routine procedures used in the CT unit at medical diagnostic department of Tripoli Medical Center is carrying CT scans four times for each patient as it is been requested the medical practitioners. It is well known fact that; medical doctors are not concerned about the amount of radiation exposure to patients and do not pay attention to it.

For these reasons the researcher has taken the advantage as being one of the CT operators at the TMC and discussed the medical doctors about lowering the patients radiation doses by decreasing the number of CT scans. The researcher has taken this initiative and discussed the final images with the practitioners and were satisfied with only or two CT scans depending on the patient case. It was also agreed with medical doctors and specialists that in order to carry-out a CT scan the patient has to provide the following :

1- Provide the necessary laboratory analysis results as requested by medical doctor,
2- Carry out an ultrasound scans on the particular organ suffering the medical problem,
3- Provide kidney function test results,
4- Give a complete history of the medical problem he suffering from.
5- Provide any previous X-ray or CT scan images.

10- Conclusions and Recommendations

In conclusion, it is clear that CT scans causes high radiation exposure which is about ten times single chest x-ray. Also, it is clear that the more CT images to be taken the more the exposure radiation doses to the patient. Therefore, there should be consensus among the medical doctors and CT operators and radiation protection specialists of lowering the medical radiation exposures to patient as low as reasonably achievable according to the rules and regulations set by ICRP 61. A certain set of CT imaging protocol should be discussed between all involved parties namely; medical doctors, radiologists, CT specialists and medical radiation protection unit at the hospital.

Upon completing this medical scientific research project it could be clearly seen that CT imaging if not treated properly and carefully it causes a high radiation exposure doses to the patients as well as to the operators and specialist. The following recommendations may be studied or introduced to TMC hospital administration that might be put into practice.

1- The collected results obtained from this research project is good indication of high dose exposure to the patient especially if the imaging is repeated more than one time for each patient.
2- CT imaging for one time should be enough to provide the needed clinical investigations.
3- The doctors should depend more on primary safer medical investigation and should make the CT imaging the final resort.
4- It is advisable that the medical physics unit at the TMC should be activated and follow the exposure doses to CT operator and specialists as well as to the patients.
5- The TMC medical physics unit should carry out workshops and training courses for all radiology department staff including the medical doctors.
6- The TMC medical physics unit should distribute personal dosimeters to measure the yearly exposure and absorbed radiation doses to department personnel and patients.
7- The radiology department should provide archiving procedures to store the CT medical patient records so they could be used as medical records and reference point for further future medical investigations.
8- A radiation field survey of the newly established TMC CT unit which is located to the corridor and patient waiting area.
9- It is well established fact that by lowering the imaging utilization of the CT it will prolong it's life time uses.
10-

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