ASSESSMENT OF PATIENT RADIATION DOSE FROM RECURRENT CT EXAMINATIONS

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Abstract- **Earlier reports showed that the patients undergoing recurrent radiological procedures can received the cumulative effective dose (CED) from 50-1000 mSv or more [1]. Several hundred hospitals in USA and European countries assessed the average percentage of 1.33(0.64-3.4) with CED ≥100 mSv among more than 2.5 million recurrent CT patients [2]. The purpose of this study is to assess the cumulative effective dose (CED) from the recurrent CT examinations at 100 mSv and above for the period of five years at one pilot, tertiary care facility in Thailand. The percentage of those patients with and without malignancy, at less than 40 years at age and above was also assessed. Methods: Initially the data was retrieved retrospectively from the Hospital Information System (HIS) then from the established radiation dose monitoring systems in 2017 by setting the threshold value of 100 mSv. The number of patients with the CED ≥ 100 mSv only from recurrent CT examinations during a period of five years was identified. The age and gender distribution of these patients were assessed to identify the magnitude of patients in the relatively lower age group of ≤ 40 years. Results: Of the 208,731 CT exams from 2015 to 2019, nineteen patients received CED ≥ 100 mSv in a single day at less than 0.01% of total CT examinations. Six patients at 22- 40 years of age and thirteen patients at 41 - 78 years of age received CED ≥ 100 mSv in a single day. The median CED was 106.7 (100.90-139.32) mSv. The acquisition protocols with the clinical diagnosis of those nineteen patients had been reported.**

Keywords- **Cumulative effective dose, CED, Recurrent CT, Radiation protection, Patient radiation dose**.

I. INTRODUCTION

The use of diagnostic CT in the United States has risen nearly 20 folds since the early 1990s and the medical imaging accounts for more than 50% of the radiation exposure, half of which related to CT scan. The rapid availability of CT, along with their diagnostic accuracy, has led to dramatically increased use in acute care. Early detection of the disease, the reduction in mean hospitalizations, had been attributed to greater use of CT. With the current expansion of CT in medical practice, an increased understanding of cancer risks and strategies for reducing radiation dose is of utmost importance. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [3], the International Commission on Radiological Protection (ICRP) [4], and the National Council of Radiation Protection and Measurements (NCRP) have successfully evaluated the radiation – related adverse effects, particularly cancer, at or above the absorbed dose of 100 mGy. The NCRP had reviewed all studies in the world at the absorbed dose below 100 mGy and concluded that the linear no- threshold (LNT) model should be used for radiation protection purposes [5]. The U.S. Food and Drug Administration [6] has stated that compared with the natural incidence of fatal cancer in the United States of approximately 1 chance in 5, an effective dose from CT of 10 mSv may be associated with the possibility of fatal cancer in approximately 1 in 2000 patients. This is similar to the overall BEIR VII cancer estimate of 1 in 1000 per 10 mSv [7]. Pearce et al. [8] documented a three times increased relative risk of leukemia among children who had received a cumulative radiation dose of at least 30 mSv. These findings appear to be consistent with the linear no-threshold model, though the American Association of Physicists in Medicine (AAPM) has responded by emphasizing the low incidence of leukemia in children [9], which can exaggerate relative risk. For elderly patients, estimates made with BEIR VII models revealed a minimally increased attributable risk (0.03–0.04%) for development of cancer related to ionizing radiation [10]. Multiple CT examinations can lead to high CED (50–200 mSv). Compared with the dose from a single CT examination, a cumulative dose of 120 mSv (approximately eight CT examinations) can increase lifetime risk of cancer development from 1 in 1000 to 1 in 82.

In 2019, the technical meeting on radiation exposure of patients from recurrent radiological imaging procedures, organized by the IAEA which the IAEA Experts and the representatives of 46 IAEA Member States had been participated on March 4 to 6, 2019 and made the summary of the findings and conclusions of (a) look at the data from different countries collected specifically for this meeting through the IAEA-MGH survey on patients with CED ≥ 100 mSv, (b) discuss available literature on patients with CED ≥ 100 mSv and radiation effects at this level of radiation dose, (c) create awareness about the findings on the number of patients with CED ≥ 100 mSv, (d) discuss limitations, if any, of the current framework on radiation protection in dealing with new findings, and (e) develop plans for future work.[1]

More data provided strong evidence of an increased cancer mortality risk at equivalent dose at greater than 100 mSv, an increased risk at doses between 50 and 100 mSv, and reasonable evidence for increased risk at dose between 10 and 50 mSv. The use of ionizing radiation for medical purpose provides many benefits, but it also increases the risk of cancer later in life. The justification and the radiation dose optimization have been continuous emphasized on, including the development of new CT technologies, [11] for the purpose of the patient dose reduction.

II. Materials and methods

The study is a retrospective, observational, at a single center. The Institutional Review Board, Faculty of Medicine Chulalongkorn University has approved the IRB 815/13 title 'The survey of the cumulative effective dose (CED) exceeds 100 mSv in a single day from diagnostic CT systems at King Chulalongkorn Memorial Hospital' on December 24, 2020. During January 2015 and December 2019, the number of patients was acquired by six CT scanners, of two Philips, two GE, one Siemens and one Canon systems. The number of CT examinations, patients, procedures and related data had been retrieved from HIS and dose tracking platform Radimetrics version 2.9b Bayer Healthcare, USA, installed in 2017. The ratio of CT exams per patient is shown in Table 1. Table 2 shows the number of CT examinations and the percentage in each year. The demographic data of the patients with CED $\geq$ 100 mSv in a single day had been collected from Radiometrics of all recurrent CT patients. A patient-level search was performed using a threshold of CED 100 mSv from January 2015 to December 2019. The effective dose (mSv) is calculated using organ weighting factor from ICRP103.[12] Since the data collection time frame ended in December 2019, the patient age was estimated in December 2019 as detail in Table 3

Table 1 Number of patients and CT exams acquired by 6 CT scanners, retrieved from the Radimetrics (2015-2019) at one tertiary healthcare center in Bangkok, Thailand.

CT scanner	Model	period	No. of patients	No. of CT exams	CT exams/ patient
Philips	Brilliance 64	2015-2018	16,158	20,839	1.29
Philips	Ingenuity	2016-2019	11,993	16,480	1.37
Siemens	SOMATOM Force	2015-2019	27,052	38,098	1.41
GE	Revolution	2017-2019	11,296	15,628	1.38
GE	Discovery750HD	2015-2019	21,453	34,478	1.61
CANON	Aquilion ONE	2015-2019	28,572	40,925	1.43
		Total	116,524	166,448	Mean 1.43

Table 2 Number of CT Examinations per year (2015-2019) collected from the HIS.

Year	Number of CT Examinations	Percent
2015	34,307	16.44
2016	40,304	19.31
2017	54,185	25.95
2018	44,208	21.18
2019	35,727	17.12
Total	208,731	100.00

III. RESULTS

Table 3 The demographic of nineteen patients with CED ≥100 mSv in a single day

Patient Number	Age at year 2019 (year)	Gender	Weight (kg)	Height (cm)	Patient diameter# (mm)	CED (mSv)
1	31	M			227.63	102.58
2	64	F	80	165	347.71	116.07
3	64	F			267.89	102.17
4	53	F	160		419.73	101.56
5	62	F♯			256.57	105.01
6	59	F♯	70		300.91	111.17
7	57	F	67		258.26	139.32
8	23	M	80	170	205.70	110.41
9	36	M			276.99	101.68
10	35	F	55		244.23	103.80
11	61	M			316.56	100.90
12	52	M	170		441.38	113.24
13	28	F			274.37	103.15
14	78	F			262.69	109.43
15	79	M	75	165	317.94	113.78
16	38	F	72.6	160	399.20	121.39
17	73	M	70	160	300.98	101.54
18	70	M	62		265.15	122.23
19	61	M	59.2		220.27	106.70
Mean	54.0	#	85	164	295.0	110.0
Median	57.0	#	71	165	274.0	107.0
	<40 = 6 >40=13	M=9 F=10				

Table 4 Data of nineteen patients with CED ≥ 100 mSv in a single day

Total patients CED ≥ 100 mSv	Max CED (mSv)	Median CED (mSv)	Min CED (mSv)	Mean no. of CT exams/patient	Max no. of CT exams/patient	No. of Follow Up (cases)
19	139	107	100.90	4	13	9

Table 5 Patient distribution among various acquisition protocols for cohort with CED≥ 100mSv in a single day

CT Chest Whole Abdomen	CT Brain without contrast	CT Abdomen with & without contrast	CT Angiogram heart with and without contrast	Total
2	4	6	7	19

Table 6 The acquisition protocol and clinical diagnosis of six patients with CED ≥ 100 mSv in a single day at age ≤ 40 years

Patient Number	Age at 2019 (year)	Gender	No. of CT (2015-19)	CED (mSv)	Acquisition protocol	Clinical diagnosis
1	31	M	1	102.58	CTA Brain & Neck +Whole Aorta	Trauma
2	23	M	1	110.41	CT Brain+ C-Spine + CTA Upper Extremity Runoff	Trauma
3	36	M	4	101.68	CT Brain+ C-Spine +Whole Abdomen	Trauma
4	35	F	5	103.80	CT DE thoracic aorta	Takayasu arteritis
5	26	F	1	103.15	CT Brain +Facial bone +C-Spine +Whole Aorta	Trauma
6	38	F	4	121.39	CT Whole abdomen	Cryptogenic Cirrhosis

Table 7 The acquisition protocol and clinical diagnosis of thirteen patients with CED ≥ 100 mSv in a single day at age > 40 years

Patient Number	Age at 2019 (year)	Gender	No. of CT (2015-19)	CED (mSv)	Acquisition protocol	Clinical diagnosis
1	64	F	1	116.07	CT Chest +Whole abdomen	A few tiny caliceal stones
2	64	F	4	102.17	CT Brain+ Whole aorta	Trauma, Head injury
3	53	F	3	101.57	CT Whole abdomen	Morbid obesity, hypermenorrhea
4	62	F	4	105.01	CT Whole aorta with ECG-gating	Aortic arch aneurysm post TEVAR
5	59	F	13	111.17	CT Larynx + Chest +Whole abdomen	DLBCL Post 6th R –CHOP
6	57	F	5	139.32	CTA Thoracic aorta	Aortic dissection (Stanford type A)
7	61	M	8	100.90	CT Whole abdomen	Bilateral renal cyst and renal stone
8	52	M	1	113.24	CT Whole abdomen	Morbid obesity post sleeve gastrectomy
9	78	F	4	109.43	CTA Whole aorta	Concealed rupture aortic arch aneurysm post TEVAR
10	79	M	3	113.78	CT Nasopharynx + Chest +Whole abdomen	Aspiration pneumonia
11	73	M	2	101.54	CT Whole abdomen	Left stage horn stone post left PCNL
12	70	M	4	122.23	CTA Thoracic Aorta Prospective with ECG-gating	Aortic aneurysm with severe AR
13	60	M	2	106.70	CT Cardiac Prospective with ECG-gating	TVD Post CABG

IV. Discussion

The number of CT examinations per patients within five years range from 1.29 to 1.61 among 6 CT systems. The recurrent CT of 208,731 exams from the year 2015 to 2019 shows the number of the cumulative effective dose of greater than 100 mSv in a single day at 19 cases or 0.01% of all examinations. The maximum CED of 139.32 mSv in a single day is obtained by a 57 year old female with 67 kg body weight. The study protocol was a CTA Dual Energy thoracic aorta and the clinical diagnosis of aortic dissection (Stanford type A), multiple myeloma oncology. The second largest CED, 122.23 mSv, obtained by a 70 year old male whose protocol was a thoracic aorta prospective and the clinical diagnosis was an aortic aneurysm with severe aortic regurgitation. Four from six cases of young patients were trauma of two CT aorta, one CT abdomen, and one CT brain. Two from six of young patients were CT Dual Energy Aorta and one CT abdomen of cryptogenic cirrhosis. The patients at the age of over 40 years old with CED≥100 mSv consist of 6 CTA, 2 CT chest and whole abdomen, 4 CT abdomen, and 1 CT Nasopharynx.

V. Conclusion

The overall patients undergoing multiple CT exams and obtained CED ≥ 100 mSv have been assessed with the number of 19 patients whose age of less than 40 years old in 2019 was 6 and over 40 years old was 13. The total number of CT examinations was 208,731 which result in the percentage of patients with CED ≥ 100 mSv at 0.01. The percentage is much lower than the report from the survey of 324 hospitals in US and EC hospitals at 1.33(0.64-3.4). The assessment shows the requests of multiple CT scans at CED≥100mSv were CTA- trauma, CT abdomen, CT brain and CT nasopharynx respectively. There were a few cases of cancer patients at the Section of Diagnostic Radiology. The cancer patients obtain the follow up on CT study at the Section of Radiation Oncology by using CT/MR simulator. Further study at other local centers with Radimetrics dose tracking is encouraged to monitor the patients with CED≥ 100 mSv, in order to have the national data on the appropriateness in requesting for CT examination and the radiation protection of patient on the recurrent CT examinations.

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