Radiation Doses to Specific Organs/Tissues from Computed Tomography Examinations

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1. Introduction

Computed tomography (CT) is a valuable imaging tool and provides great medical benefits in modern medicine. However, high radiation doses - about hundreds times that from chest x-ray – associated with this diagnostic tool is concern. The use of CT scans has been increasing over time in all western countries [1]. The number of CT scans performed in the US has increase with annual growth rate of about 10% per year and were estimated 67 million in 2006 [2, 3]. This increasing trend is not exceptional for Korea. According to a Korean statistics, the annual grow rates were much higher than the other countries with about 20% increase rate per year. Therefore, it is necessary to recognize the potential risk from the CT use and inform the public with the information. One of good starting points for the purposes is to estimate cancer risk from CT use. The relevant measure of dose for the risk of a specific type of cancer is the absorbed dose to the appropriate organ of the body, known as the organ-specific radiation dose. However, most available data have provided effective doses rather than organ doses for CT examinations. Present study provides organ dose estimates in addition to effective dose from various types of CT examiantons.

2. Materials and Methods

Radiation doses were estimated using CT-Expo version 1.6 [4]. The program uses organ dose databases generated based on Monte Carlo radiation transport modeling by National Research Center for Environment and Health (GSF) in Germany [5, 6]. Radiation dose from CT scans varies depending on examination type, CT scanner, and technical parameters settings (e.g., scan region, scan length, scan mode, current-time product, tube potential, pitch, etc.). Not only common types of CT examinations (e.g., head scan, chest scan, etc.) but also some special examinations were included for this dosimetric study. Six of the most commonly used CT scanner groups were used for dose estimation and then the averages were calculated. Typical technical parameters were taken from a US nation-wide survey [7]. The survey did not include some special examinations, including coronary artery calcification (CAC), virtual colonography (CTC), and CT angiography (CTA). For the cases, recent literature was reviewed to obtain the parameters [8, 9]. For scan mode, it was assumed that all scans were helical scans except those of the head and spine, which are still most commonly performed as axial scans [7].

3. Results and Discussion

Tables-1 shows organ doses from different types of CT examinations. Organ doses greatly depend on anatomical region of CT scanning. Radiation dose is high for organs entirely exposed to direct beam (~ > 10 mGy), moderate to organs partially exposed to directly beam or organs at vicinity to the direct beam (1 - 10 mGy), and very small to the organs away from the scan region (~ < 1 mGy). Organs/tissues distributed across whole body (e.g., skin, bone surface, bone marrow) also received relatively high radiation doses. The radiation dose to the brain is higher than other organs within scan region because head CT generally employs much higher intensity of x-ray beams (or mAs) due to the need for bone box penetration.

Table 1A. Organ and effective doses from CT examinations (Male)

Radiation Dose	Radiation Dose by CT Examination (mGy)						
	Head	Chest	Abd /Pel	Whole body	CAC	CTC	CTA [1]
Effective	2.1	6.0	10.3	11.5	1.7	3.4	10.9
Thyroid	2.4	11.8	0.1	3.4	0.1	0.0	1.2
Breasts	-	-	-	-	-	-	-
Esophagus	0.1	19.2	0.4	18.7	1.2	0.1	7.7
Lungs	0.1	20.0	2.6	20.1	7.7	1.1	51.2
Liver	0.0	7.8	17.8	18.4	3.4	5.8	21.2
Stomach	0.0	5.4	18.9	18.5	2.1	6.1	13.0
Colon	0.0	0.2	17.6	14.8	0.1	5.6	0.6
LLI	0.0	0.0	16.3	12.2	0.0	5.2	0.1
Gonads	0.0	0.0	9.8	1.4	0.0	3.4	0.0
Bladder	0.0	0.0	18.3	14.7	0.0	5.9	0.0
BM	5.7	4.9	8.4	10.9	1.2	2.7	7.6
BS	13.5	13.2	12.4	20.6	3.5	4.1	23.0
Skin	3.2	4.8	7.2	9.1	1.3	2.4	8.3
Brain	42.9	0.3	0.0	0.2	0.0	0.0	0.0

Abbreviation: BM (bone marrow), BS (bone surface) Abd/Pel (abdomen/pelvis), CAC (coronary artery calcification), CTC (CT virtual colonography), and CTA (CT angiography)
[1] Coronary CTA

Table 1B. Organ and effective doses from CT examinations (Female)

Radiation Dose	Radiation Dose by CT Examination (mGy)						
	Head	Chest	Abd /Pel	Whole body	CA C	CTC	CTA 1
Effective	2.1	6.0	10.3	11.5	1.7	3.4	10.9
Thyroid	2.4	11.8	0.1	3.4	0.1	0.0	1.2
Breasts	-	-	-	-	-	-	-
Esophagus	0.1	19.2	0.4	18.7	1.2	0.1	7.7
Lungs	0.1	20.0	2.6	20.1	7.7	1.1	51.2
Liver	0.0	7.8	17.8	18.4	3.4	5.8	21.2
Stomach	0.0	5.4	18.9	18.5	2.1	6.1	13.0
Colon	0.0	0.2	17.6	14.8	0.1	5.6	0.6
LLI	0.0	0.0	16.3	12.2	0.0	5.2	0.1
Gonads	0.0	0.0	9.8	1.4	0.0	3.4	0.0
Bladder	0.0	0.0	18.3	14.7	0.0	5.9	0.0
BM	5.7	4.9	8.4	10.9	1.2	2.7	7.6
BS	13.5	13.2	12.4	20.6	3.5	4.1	23.0
Skin	3.2	4.8	7.2	9.1	1.3	2.4	8.3
Brain	42.9	0.3	0.0	0.2	0.0	0.0	0.0

Radiation dose from CT examination depends on not only examination types but also CT practice at CT center. There was wide variation in radiation doses for the same type of CT examination. It was not unusual to observe more than an order of magnitude difference between the maximum and the minimum radiation doses estimated using different CT parameter settings used in different CT centers. It can be attributed to wide variation in CT practice by CT center.

3. Conclusions

Organ doses and effective doses from various types of CT examinations were estimated. Radiation doses greatly varied depending on examination types and CT centers. Wide variations in radiation dose were observed for the same type of CT examination. The variation may be as much as one order of magnitude. The wide variation in these doses strongly suggests that more attention must be paid to control radiation doses to patients and to develop optimized protocols of CT examinations.

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