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Original Research Article

Comprehensive Study of the Evaluation of Radiation Dose in Different Chest CT Protocols at SGT Hospital, Gurgaon

Mohit Kumar Dahiya[1], Jyoti[2]

[1,2]Department of Radio-Diagnosis, SGT University, Gurgaon, Haryana, India.

Corresponding Author: Mohit Kumar Dahiya

ABSTRACT

Computed tomography is higher modality of X-RAY imaging. In computed tomography the doses are generally expressed in $CTDI_{VOL}$, DLP. The purpose of this study was to evaluate the radiation doses between different chest CT protocols. The aim of this study was to evaluate and compare the radiation dose in different chest CT protocols. $CTDI_{VOL}$ and DLP doses were obtained from routine CT chest examination (NCCT, CECT, HRCT Vol., and HRCT SEQ). The prospective study was done at SGT hospital in rural area of Gurgaon, Haryana. The study was carried out in 60 patients including 15 patients of each protocol. The mean value of CTDI VOL and DLP were respectively: 5.643mGy and 214.69mGy*cm for NCCT chest, 11.33mGy and 392mGy*cm for CECT chest, 6.34mGy and 221.66mGy*cm for HRCT volumetric and 2.41 mGy and 77.13mGy*cm for HRCT sequential. The study shows result with highest radiation doses in contrast enhanced computed tomography among all the chest protocols.

Keywords: AERB- Atomic Energy Regulatory Board, CECT- Contrast Enhanced Computed Tomography, Cm- Centimeter, CTDI- Computed Tomography Dose Index, CT- Computed Tomography, DLP- Dose Length Product, Gy- Gray.

INTRODUCTION

The term “computed tomography”, or CT, is basically referred to a computerized X-ray imaging procedure in which X-rays are projected at a patient and also rotates around the body, producing signals that are processed by the computer to produce cross-sectional images or “slices or sections” of the body (Kalra M, 2004).[1]

1.1 History of Computed Tomography

Computed tomography was discovered by Sir Godfrey Hounsfield of EMI laboratories in 1972. Hounsfield and Comark were later awarded the Nobel Peace Prize in 1979 for their contributions to medicine and science (L., 2011).[2]

The first CT scanner was installed between 1974 and 1976. At that time CT scans machine were only used for dedicated head imaging, but "whole body" CT scanner systems became available in 1976. Slip ring technology was discovered in 1989 and this cause a drastic change in the field of Computed Tomography imaging by which there is no wear and tear of cable in hardware of Computed Tomography. Slip ring technology principle involves rotating an X-ray tube on slip metallic ring without any outer cable connection. The X-ray tube

is revolving on a stationery ring by the help of brushes. Brushes provide two functions to X-ray tube first is to support to revolve around patient and second is to pass electricity to X-ray tube from stationery metallic ring. This made continuous rotation of X-ray tube with continuous increment in CT table couch. In 1998, multi slice computed tomography was developed by which single breath- hold scans could be possible (N., 2013).[3]

1.2 Principle of Computed Tomography

The principle of computed tomography is internal structure of an organ or body can be reconstructed by revolving X-ray tube around the patients. CT is based on the fundamental principle that the density of the body organs or tissue passed by the X-ray beam can be measured from the calculation of the attenuation coefficient (Imaginis - The Women's Health & Wellness Resource Network, Brief History of CT | CT Scan | Imaginis - The Women's Health & Wellness Resource Network [Internet]. Ima2019).[4]

1.3 Helical or spiral Computed Tomography

This technique is possible with the help of slip ring technology in which X-ray tube rotates continuously with continuous increment in CT couch by which X-ray tube makes an imaginary helical or spiral trajectory around CT patient couch(N., 2013).[3]

1.4 Multi-slice Computed Tomography

The CT scanner developed by Sir Godfrey Hounsfield took several hours to generate a single slice image. The latest multi-slice CT systems can collect up to 4 slices of data in about 350 ms and reconstruct images in less than a second. An entire chest can be scanned in five to ten seconds using the most advanced multi-slice CT system (D., 2009).[5]

In last 45 years, CT scans machine has made great improvements in time, patient comfort, speed and image resolution. Now after 45 years, CT scanner is very much faster, allow more anatomical coverage in less time, faster technique reduces motion artifacts of patient and using slip ring technology and spiral CT technique even a single breath-hold scan is made possible. CT exams are now faster and have optimum radiation dose than ever before. Tremendous research and development has been made it possible to provide excellent image quality for diagnostic confidence at the lowest possible radiation dose.

1.5 Computed Tomography Dose Index (CTDI)

Dose represents the amount of energy deposited in tissue from radiation per mass of tissue in J/kg. Computed tomography is basically shooting of X-rays from multiple angles along the length of the object. In order to derive the CT radiation dose CT dose index was discovered (D., 2009),(Mihandoost E, 2018).[5,6]

$CTDI_{100}$ – It is the linear measure of dose distribution over a 100 mm long pencil beam ionization chamber

$CTDI_W$ - 2/3 $CTDI_{100}$ (periphery) + 1/3 $CTDI_{100}$ (center)

$CTDI_{VOL}$ - it is obtained by dividing $CTDI_w$ by **pitch factor**

1.6 Dose Length Product (DLP)

In CT, the total amount of radiation incident on the patient, known as the DLP, is the product of the $CTDI_{vol}$ and scan length (in centimeters) and is measured in milligray-centimeters. The DLP is the second dose metric that is easily accessible to the radiologist and accounts for both radiation intensity ($CTDI_{vol}$) and scan length in the CT scan examination. DLP data, therefore, indicate the total amount of radiation (ie, intensity × scan length) used to perform the CT examination and is quantified in a cylindrical phantom of a specified size (ie, 16 or 32 cm in diameter) (Mihandoost E, 2018), (Tsapaki V, 2001).[7,8]

MATERIALS & METHODS

A prospective study was carried out over 6 months in radiology department of SGT hospital, Gurgaon, Haryana. This study was carried out on 16 slices Computed Tomography machine and this study has been conducted first time on this machine at SGT hospital. In this study, OUT patient of

SGT Hospital were included who went through HRCT and routine chest tomography. There is no patient age bar and no sex bar both male and female patient were included in this study. In this study, the IPD patient, trauma patient, ICU patient of SGT Hospital were also included. The study has been carried out from 1st October 2017 to 31st march 2018.The data was collected on daily routine from CT machine in the form of CTDI and DLP which is maintained over a period of 6 months and this data was analyzed to compare the different dose between HRCT chest and chest routine CT. The analysis of chest radiation doses was made on the basis of dose reports from 60 examinations. All examinations used for dose analyses were standard, fully diagnostic examinations, and no scan was listed as rejected in periodic quality control analyses of CT scans. Any doubts were decided by consensus and all analyzed scans were considered to be diagnostic scans (Sarma A, 2012).[9]

2.1 Project and Study Design

In an effort to improve the quality of SGT hospital healthcare the study is carried out to minimize the radiation dose and give optimum quality images. To perform this study SGT hospital was used to develop a database of radiation dose information per patient undergoing different chest CT protocols. The values from each protocol and in every patient were compared to find out the dose comparison between different chest CT protocols (Gorycki T, 2014).[10]

2.2 Setting and Resources

The project setting was in SGT hospital located in a rural area of Gurgaon district of Haryana. The hospital is equipped with a Siemens somatom scope 16 slices CT scanner.

2.3 Study Population

The population consisted of adult patients with known or unknown chest related problems undergoing CT scans of the chest with and without contrast. Sample included random number of subjects admitted in the hospital or outpatient of hospital that underwent different chest CT protocols between the months of October 2017 and March 2018. The final number of CT scans during that period totaled is 60. Written consent in the language understood by the patient was taken before the test.

2.4 Plan

To manage the risks of CT examinations depends on two basic principles of radiation protection: justification for examination, and careful optimization of the radiation dose used during each examination. ALARA principle should be used to get a high quality image by using optimal radiation dose.

2.5 Sample size:

In this study, investigator used the most appropriate routine protocols of all chest CT scans. A total of 60 patients are included in this study to find out the variation in radiation doses in different chest CT protocols.

TABLE 1: Shows Sample Size of the study

Examination	Number Of Patients
NCCT CHEST	15
CECT CHEST	15
HRCT CHEST SEQUENTIAL	15
HRCT CHEST VOL	15
TOTAL	60

2.6 Radiation Dose Measurement

This prospective study was performed on $CTDI_{VOL}$ values expressed in mGy and DLP values expressed in mGy*cm, which are measured from the dose reports showing radiation exposure in various protocols used in chest examinations. A total of 60 patients using a 16 slice SOMATOM scope CT scan machine of Siemens used to taken out this study.

2.7 Calculations of CTDI Volume and DLP

Collection of data in this prospective study was achieved by the use of computed tomography dose report. Patient who were visited radiology department for chest CT from 1 October, 2017 to 31 march, 2018, the dose report of all these patient are maintained in a excel sheet. All CT

protocols and dose reports were evaluated at the end of data collection. The data of CTDI and DLP were recorded from the dose report of the patient which was derived from raw data of computed tomography study of each patient.

A excel sheet was maintained to record the patient data. CTDI and DLP were recorded after each patient in excel sheet. To calculate statistically difference between different chest protocol "One Way Anova Test" was applied to CTDI and DLP value.[11]

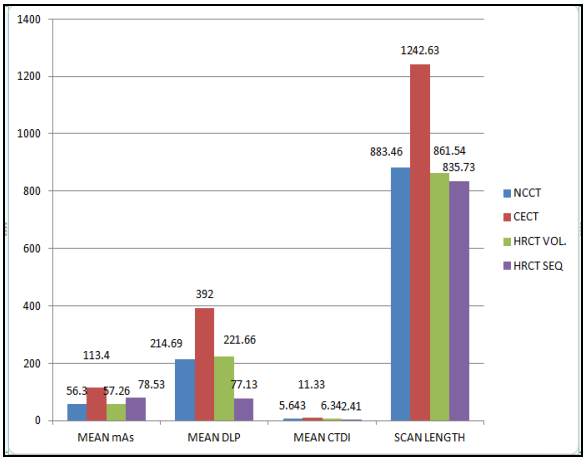
RESULT

By using CT scan data that was collected from CT scanner machine at SGT hospital. CTDI and DLP doses were recorded randomly from 60 patients of different chest CT protocol. The result shows that the mean age of CECT chest protocol has highest mean DLP dose and highest mean CTDI vol. dose as compared to mean age of NCCT, HRCT volume, HRCT sequential protocols patients.

The minimum aged patient to undergo non contrast computed tomography was 20 years, for contrast enhanced computed tomography was 22 years, for high resolution computed tomography volumetric scan was 13 years, for high resolution computed tomography sequential was 21years. The minimum aged patient to undergo HRCT vol. scan was 13 years old.
The comparison of mean mAs, mean DLP value, mean CTDI values and mean scanning length of all the different chest CT protocols are shown in table 2 and graph 1 shows the graphical representation of comparison of mean age, mean DLP value, mean CTDI values and mean scanning length of all chest CT protocols. The maximum mean DLP and maximum CTDI was in mean age of CECT patient.

TABLE 2: Comparison of mean mAs, mean DLP, mean CTDI between different chest CT protocols

PROTOCOL	MEAN mAs	MEAN DLP mGY*cm	MEAN CTDI mGY	MEAN SCAN LENGTH mm
NCCT	56.3	214.69	5.643	883.46
CECT	113.4	392	11.33	1242.63
HRCT VOL.	57.26	221.66	6.34	861.54
HRCT SEQ	78.53	77.13	2.41	835.73



Graph 1: Comparison of mean mAs, mean DLP, mean CTDI between different chest CT protocols

The mean CTDI volume of non contrast chest CT is 5.643mGy at a mean scan length of 883.46mm. The mean CTDI volume of contrast enhanced chest CT is 11.33mGy at a mean scan length of 1242.63mm. The mean CTDI volume of high resolution Computed Tomography volumetric is 6.342mGy at a mean scan length of 861.54mm. The mean CTDI volume of high resolution Computed Tomography sequential is 2.41mGy at a mean scan length of 835.73mm.

On an average scan length of 800mm of all different chest CT protocol, the average CTDI volume of non contrast Computed Tomography chest is 5.10mGy, the average CTDI volume of contrast enhanced Computed Tomography chest is 7.294mGy, the average CTDI volume of high resolution Computed Tomography volumetric chest is 5.88mGy, the average CTDI volume of high resolution Computed Tomography sequential chest is 2.30mGy.

The mean CTDI volume of NCCT chest is 5.643mGy at mean mAs of 56.3. The mean CTDI volume of CECT is

11.333mGy at mean mAs of 113.4. The mean CTDI volume of HRCT volumetric is 6.342mGy at mean mAs of 57.26. The mean CTDI volume of HRCT sequential is 2.41mGy at mean mAs of 78.53. On an average mAs of 10 of all different chest CT protocols, the average CTDI volume of NCCT chest is 1.00mGy,the average CTDI volume of CECT chest is 0.9mGy, the average CTDI volume of HRCT volumetric chest is 1.1mGy , the average CTDI volume of HRCT sequential chest is 0.3mGy. The mean CTDI volume of NCCT chest is 5.643mGy at mean DLP of 214.7mGy*cm. The mean CTDI volume of CECT chest is 11.33mGy at mean DLP of 392mGy*cm. The mean CTDI volume of HRCT volumetric is 6.342mGy at mean DLP of 57.26mGy*cm. The mean CTDI volume of HRCT sequential is 2.41mGy at mean DLP of 78.53mGy*cm. On an average DLP of 100mGy*cm of all different chest CT protocols, the average CTDI volume of NCCT chest is 2.62mGy, the average CTDI volume of CECT chest is 2.8mGy, the average CTDI volume of HRCT volumetric is 2.86mGy, the average CTDI volume of HRCT sequential is 3.06mGy. The mean CTDI volume of CECT chest is highest in all of other different protocols mainly due to scanning length of CECT chest protocol. Scanning length of CECT chest is almost double that of NCCT chest protocol and also due to double exposure. The maximum effective mAs is also in CECT chest protocol which is 113.4. After CECT chest the highest mean CTDI volume is of HRCT volumetric protocol among all other protocols. The minimum CTDI volume is of HRCT sequential among different chest CT protocols. This is due to the minimum scanning length of HRCT sequential chest. The maximum DLP is of CECT chest protocol which is 392mGy*cm, again because of double exposure. The minimum DLP is of HRCT chest sequential protocol which is 77.13mGy*cm. By all data which is collected over a period of 6 months at SGT hospital, the result of this study is that the maximum radiation dose among various chest protocols is in CECT chest protocol. While comparing HRCT sequential and HRCT volumetric, it is found that HRCT volumetric chest protocol has higher radiation dose than HRCT sequential.

Summary of Data					
	Ctdi				
	1	2	3	4	Total
N	15	15	15	15	60
∑X	169.95	36.28	95.19	84.81	386.23
Mean	11.33	2.4187	6.346	5.654	6.437
$\sum X^2$	1996.2097	91.918	664.9709	490.3273	3243.4259
Std. Dev.	2.2468	0.5457	2.0856	0.8788	3.5824
Result Details					
Source		*SS*	*df*	*MS*	
Between-treatments		610.6473	3	203.5491	*F* = 77.77972
Within-treatments		146.5517	56	2.617	
Total		757.199	59		

	DLP				
	1	2	3	4	Total
N	15	15	15	15	60
∑X	5880.13	1156.95	3325.68	3220.42	13583.18
Mean	392.0087	77.13	221.712	214.6947	226.386
$\sum X^2$	2356268.8381	94235.0933	842807.7056	722583.3298	4015894.9668
Std.Dev.	60.4784	18.8974	86.7939	47.1898	126.2798
Result Details					
Source	*SS*		*df*	*MS*	
Between-treatments	748001.322		3	249333.774	*F* = 72.40282
Within-treatments	192847.3296		56	3443.7023	
Total	940848.6516		59		

Figure 3.2: one way ANOVA Statistics

One way Anova statistical test was run to find out the statistical difference between different chest ct protocols. Figure 3.2 shows the data for ANOVA statistical test. The test was run on online calculator to find out the result.

The *f*-ratio value for Ctdi value is 77.77972. The *p*-value is <.00001.the result is significant at $p<.05$. The *f*-ratio value for Ctdi value is 72.40282. The *p*-value is

<.00001.the result is significant at p<.05(www.socscistatistics.com).[11]

DISCUSSION AND CONCLUSION

This study implied that the CECT chest protocol has highest radiation than other CT chest protocols i.e. NCCT, HRCT sequential, HRCT volumetric. The radiation dose from above mentioned protocols can be reduced by different method such as; by using optimum mAs, by reducing kVp, by using optimum scan length, by using optimum scan exposure time and also by optimum pitch. This study shows positive result with highest radiation dose in contrast enhanced computed tomography among all the protocols of CT chest (McCollough CH, 2006),(Cody DD, 2010)(Lin C 2015).[12,13,14]

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