Low Dose High Resolution Computed Tomography of Chest by Reduction of Effective mAs by 50%: A Prospective Study

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ABSTRACT

Introduction: The objective of our study was to evaluate diagnostic acceptability of image quality in High Resolution Computed Tomography (HRCT) of chest with 50% reduction in effective mAs.

Materials and Methods: This prospective cross-sectional study was done in 104 patients with BMI less than 30 kg/m^2 who underwent HRCT chest examination in Tribhuvan University Teaching Hospital (TUTH) for the period of 4 months from August to November 2017. CT scans were performed on the Siemens Somatom Definition AS+ 128 slice CT scanner. 52 patients were scanned with routine HRCT protocol of the department while another 52 patients were scanned reducing the effective mAs selected by CARE Dose4D by 50% (low dose HRCT chest protocol), keeping other parameters unchanged. The first patient was scanned with the routine protocol while the next patient was scanned reducing the effective mAs by 50% and so on alternately. These images were evaluated by faculty radiologist and the overall image quality was assessed and scored on 4 point scale ranging from 1 to 4, (1= Excellent, 2= Very Good, 3= Fair, 4= Poor).

Results: There was no statistically significant difference between the images obtained by routine protocol and with low dose protocol across all BMI categories ($p<0.05$). Reduction of effective dose was found to be 50.71%, 47.52% and 45.94% in overweight (25-30 kg/m^2), underweight (below 18.5 kg/m^2) and normal (18.5-24.9 Kg/m^2) BMI category respectively, with overall average dose reduction of 48%.

Conclusion: Image quality of low dose protocol is acceptable for patients with BMI less than 30kg/m^2. Thus, reduction in radiation dose by approximately 50% is possible by using a low dose HRCT chest protocol.

Keywords: CARE dose 4D; CARE kV; CTDIvol; HRCT chest; Image quality.

INTRODUCTION

The technological advancements in recent years have enhanced the clinical applications of computed tomography (CT). Though the benefits of CT exceed the harmful effects of radiation the subject receives from it, increasing radiation doses to the population have raised an alarming scenario for reduction of radiation exposure [(1)]. A single chest CT examination typically delivers more than a hundred times the radiation dose of a routine frontal and lateral chest X-ray and patients may receive multiple CT scans over time for the follow-up and other clinical questions [(2)].

The estimated annual CT examinations increased by sevenfold from 2.8 million in 1981 to 20 million in 1995 in United States. CT examination contributes disproportionately to the collective diagnostic radiation dose; for instance, in England, it has been estimated that approximately 4% of radiology procedures are CT examinations, but their contribution to the collective dose is about 40% [(3)]. There are various techniques developed to reduce the radiation dose including Automated Tube Current Modulation (ATCM), X-ray beam collimation, filtration, appropriate CT technique, lower tube voltage and noise control strategies in reconstruction & data processing. These techniques along with the application of the principle of ALARA, examination specific and patient specific dose reduction techniques are relevant dose reduction techniques [(4-7)]. CT scan with low dose techniques should be adopted whenever possible unless it affects diagnostic or clinical management decision [(7, 8, 9)].

High-resolution CT (HRCT) of the chest, also referred to as HRCT chest or HRCT of the lungs, refers to a CT technique in which thin-slice CT images are obtained and post-processed in a high-spatial-frequency reconstruction algorithm6. This technique obtains images with better lung detail. HRCT is an ideal CT technique for the assessment of diffuse interstitial lung disease, pulmonary micronodules, small airway diseases, bronchiectasis along with cystic lung diseases. It is also the technique of choice for evaluation of patients with connective tissue diseases, demonstrating the presence, gross characteristics and distribution of pulmonary disease with greater sensitivity than conventional chest radiographs[(7,8)].

Given some of the anatomic peculiarities of the chest, such as high contrast and low attenuation of lungs, HRCT can be performed at substantial dose reduction [(6).] Radiation dose optimization for chest CT is of paramount importance because it is often associated with direct exposure to some of the most radiation sensitive organs, including thyroid, breast, and lungs. Given some of the anatomic peculiarities of the chest, such as high contrast and low attenuation of lungs, chest CT can be performed at substantial dose reduction, without significant degradation of image quality for diagnosis [(6)]. Thus, we carried out this study to evaluate the diagnostic acceptability of HRCT chest images with 50% reduction of effective mAs.

MATERIALS AND METHODS

This study was a prospective cross-sectional study carried out in 104 patients undergoing HRCT Chest examination with BMI less than 30 kg/m^2 at Department of Radiology and Imaging, Tribhuvan University Teaching Hospital (TUTH), Kathmandu, Nepal for the period of 4 months from August to November 2017. Purposive sampling method was used for the selection of the subjects to be enrolled in the study. All the patients undergoing HRCT chest examination during that period of time were included in the study. Obese patients having BMI > 30 Kg/m^2 and the images with artifacts were excluded.

Patients undergoing HRCT chest were randomly divided into two groups (52 patients in each group) and were scanned in Siemens Somatom Definition AS^{+} 128 slice CT scanner having Syngo.via software for image quality assessment. One of the group was examined using routine HRCT chest protocol (CARE Dose4D switched ON at 120 kVp tube potential) which was the control group of the study whereas, another group of patient (experimental group) was examined by reducing the effective mAs selected by CARE Dose4D to 50% by switching CARE Dose4D off and keeping the tube potential at 120 kVp (low dose HRCT chest protocol), while keeping all other technical parameters as it is. The first patient was scanned with the routine protocol while the next patient was scanned reducing the effective mAs by 50% and so on alternately. The reconstruction algorithm used was B70f very sharp and the window width and window level were 1200 and -600 respectively.

After the examination, the required data (kVp, effective mAs, CTDIvol and DLP) was collected from the CT console and then the overall image quality was assessed and scored by a faculty radiologist. The radiologist was not informed about the techniques used to acquire the image. The image was reviewed on the syngo.via workstation. Scoring was done on 4 point scale ranging from 1 to 4 where: 1= Excellent, 2= Very Good, 3= Fair with image quality deteriorated but there is no diagnostic limitation and 4= Poor with image quality deteriorated with diagnostic limitation.

The reviewers reviewed the images in workstation for quality score based on following criteria given by European guidelines [10].

- Visualization of:
- Entire field of lung parenchyma
- Critical reproduction
  - Visualization of:

    Entire field of lung parenchyma
  - Critical reproduction
  - Visually sharp reproduction of the lung parenchyma
  - Visually sharp reproduction of pulmonary fissures
  - Visually sharp reproduction of secondary pulmonary lobular structures such as interlobular arteries
  - Visually sharp reproduction of large and medium sized pulmonary vessels
  - Visually sharp reproduction of small pulmonary vessels
  - Visually sharp reproduction of large and medium sized bronchi
  - Visually sharp reproduction of small bronchi
  - Visually sharp reproduction of the pleuromediastinal border
  - Visually sharp reproduction of the border between the pleura and the thoracic wall

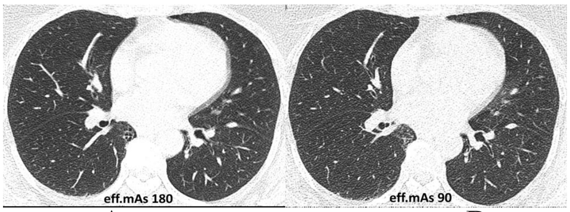

Fig-1: A-HRCT lung image obtained in the control subject with the normal protocol B- HRCT lung image obtained in the control subject with 50% mAS reduction

Data Analysis

Statistical analysis was carried out with the help of SPSS version 23 and Microsoft Excel version 2013. One-Way ANOVA test was used to compare the significance of variance in image quality between two groups. P value less than 0.05 was considered to be statistically significant.

RESULTS

A total of 104 patients were enrolled in this study. Among them 55 patients were male and 49 were female.

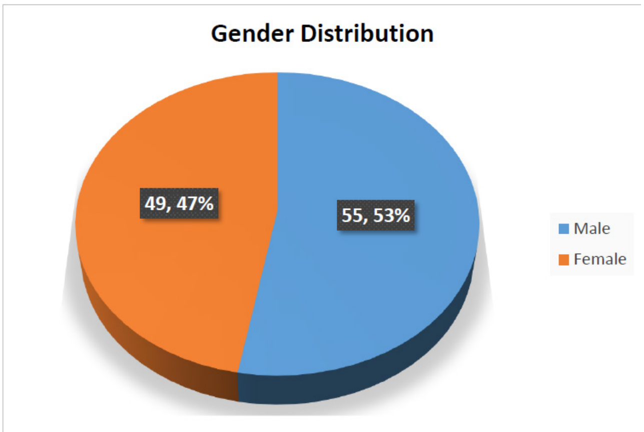

Fig-2: Gender distribution in the study

The mean age was 44.71 years ± 14.78 years. The range of age was 16-76 years. The mean weight and height was 54.08 kg ± 10.86 kg and 156.77 cm ± 9.68 cm respectively with the range being 30-75 kg and 137.16-182.88 cm respectively. The mean body mass index of the study population was 21.94 kg/m^2 ± 3.82. The highest BMI was 29.95 kg/m^2 and the lowest was 13.62 kg/m^2.

Table 1: Descriptive Statistics of Population

Patient Parameters	Maxi-mum	Mini-mum	Mean	Standard Deviation (SD)
Age (years)	76	16	44.71	14.78
Weight (kg)	75	30	54.08	10.86
Height (cm)	182.88	137.16	156.77	9.68
BMI	29.95	13.62	21.94	3.82

The mean image quality score was 1.81 ± 0.40 and 1.85 ± 0.36 for the control group and experimental group respectively suggesting that the image quality was slightly better in control group. The significance of this difference was assessed by one-way ANOVA. The results showed that the difference between the image quality of scans obtained from routine and 50% effective mAs reduction CT protocol was statistically not significant at $p<0.05$ ($p=0.60$), implying that an acceptable image can be obtained by reducing the effective mAs by 50% from the value determined by CARE Dose4D. The mean scores for low dose (reduced mAs) HRCT chest across three BMI categories were 1.9 ± 0.32 (underweight), 1.79 ± 0.41 (normal BMI) and 1.92 ± 0.28 (overweight). However, their differences in mean scores were found to be statistically insignificant at $p<0.05$ ($p=0.50$). The mean scores for routine HRCT chest across three BMI categories were 1.9 ± 0.32 (underweight), 1.83 ± 0.38 (normal BMI) and 1.69 ± 0.48 (overweight). However, their differences in mean scores were found to be statistically insignificant at $p<0.05$ ($p=0.44$). The difference in mean scores of control and experimental groups between same BMI categories were also found to be statistically insignificant at $p<0.05$ ($p=1$ for underweight, $p=0.74$ for normal and $p=0.15$ for overweight BMI categories). Further, there were no cases where the image was significantly degraded. All the cases were reported without any complains related to the technique used to acquire the image.

The mean effective mAs for control group and experimental group were 84.63 ± 22.67 and 47.19 ± 12.82 respectively. The average effective dose was estimated by using European conversion coefficients (0.014 for chest) to the DLP value that was displayed on the scanner. The scanner displayed value was taken for both CTDIvol and DLP. The mean CTDIvol, DLP and effective dose for routine CT protocol was found to be 6.27 ± 1.75 mGy, 209.49 ± 62.22 mGy.cm and 2.93 ± 0.88 mSv respectively, whereas, the mean CTDIvol, DLP and effective dose for 50% mAs reduction CT protocol was found to be 3.3 ± 1.0 mGy, 109.85 ± 34.38 mGy.cm and 1.54 ± 0.48 mSv respectively (Figure 11, Figure 12, Figure 13). The amount of dose reduction was 47.05% in CTDIvol, 47.57% in DLP and 47.57% in effective dose when effective mAs was reduced by 50% (Figure 14). Reduction of 50.71% effective dose was seen in overweight BMI category followed by 47.52% in underweight BMI category and 45.94% in normal BMI category.

Table 2: Descriptive statistics of protocol parameters

Para-meters		Maxi-mum	Mini-mum	Mean	SD
Effective mAs	Routine protocol	150	48	84.63	22.67
	Low dose protocol	90	27	47.19	12.82

CTDIvol	Routine protocol	12.14	3.27	6.27	1.75
	Low dose protocol	6.77	1.68	3.32	1.00
DLP	Routine protocol	418.20	90	209.49	62.62
	Low dose protocol	227	46.4	109.85	34.38
Effective dose	Routine protocol	5.85	1.26	2.93	0.88
	Low dose protocol	3.18	0.65	1.54	0.48

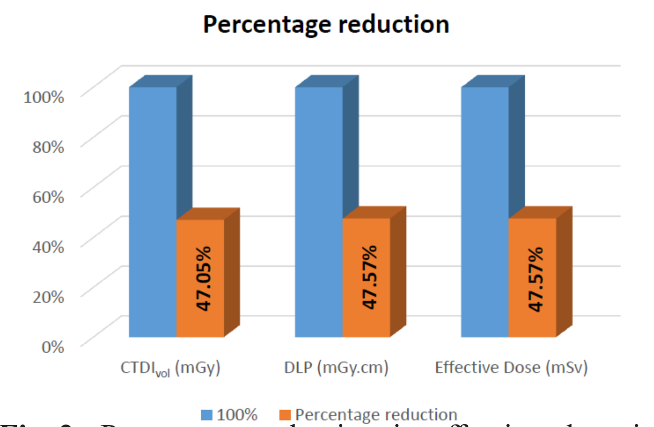

Fig 2: Percentage reduction in effective dose in different BMI categories

We also evaluated the findings of the patients and found fibrotic changes to be the most common in both low dose and routine protocol followed by lymphadenopathy, atelectasis and bronchiectasis. The summary of the findings are listed in the following table.

Table 3: Summary of findings

Findings	Low Dose Protocol	Routine Protocol
Ground Glass Opacity	3	5
Emphysema	3	4
Micro-Nodules	4	1
Tree in Bud opacities	4	6
Reticular opacities	1	1
Honeycombing	2	1
Bronchiectasis	11	10
Bronchial Wall Thickening	2	0
Fibrotic Changes	28	24
Thickened pleura	1	0
Pleural effusion	4	1
Pericardial Effusion	1	0
Atelectasis	12	10
Air bronchogram	0	1
Benign Calcification	7	9
Consolidation	5	5
Bulla	2	3
Cysts	3	6
Cardiomegaly	2	4
Lymphadenopathy	14	16
Normal	3	2

DISCUSSION

The number of CT examination is increasing rapidly with increasing technological advancements, though it contributes a significant amount of radiation dose to patients. In spite of constituting only about 5% of radiological examination, CT contributes more than 34% of radiation exposure from medical X-ray sources [11]. Some authors have suggested that chest CT in women less than 35 years of age would increase the risk of breast cancer by 35%. In addition, chest CT also causes direct radiation exposure to major radiosensitive organs of the body [11].The lifetime risk of developing cancers due to radiation because has been a matter of concern, especially in regard to pediatric population undergoing CT examinations. Using the linear extrapolation algorithm, Brenner et al [3] estimated that 500 out of 600,000 children (<15 years old) undergoing CT examination might develop cancers as a direct result of CT scans obtained in the United States.

There are many methods for reduction of radiation dose delivered by CT and the major factor governing the amount of radiation output given by CT is the mAs (effective mAs for helical CT). Lowering mAs is one of the major techniques used to lower the radiation dose. In addition, the inherent high contrast and low attenuation of lungs are favorable for low mAs techniques. Therefore, chest is an area which seems appropriate for low dose CT imaging by reducing the mAs. Our study was focused on reducing the radiation dose by decreasing the effective mAs assigned by dose modulation option CARE Dose4D available in the scanner by 50% in HRCT chest examinations and also examine the image quality when the mAs is reduced. The results showed acceptable image quality for all the patients included in the study who were scanned with reduction of effective mAs by 50%. All of these cases were reported without any complaints by radiologist. The average dose reduction achieved was found to be 48%.

Corneloup O et al[12] estimated about 50% reduction in dose employing a low mAs protocol and the result showed a perfect correlation and agreement between the image quality of the two sets images obtained using routine and reduced mAs technique. The mean DLP in their study was 53.4 mGy.cm and 25.1 mGy.cm for routine and low dose technique respectively. Although the dose reduction percentage calculated in this study was comparable to our study, the mean DLP was significantly lower in our study. This difference may be because their study used 1 mm thick images at 10 mm interval whereas our study used volumetric acquisition. A recent study by Kubo T et al [7] demonstrated that the image interpretation results of low dose (50 mAs) CT for the assessment of intrathoracic abnormalities are comparable to that of standard dose (150 mAs) CT image. They assumed the length of scan to be 30 cm and their estimated value of effective dose was 3.57 mSv for low dose CT protocol. This value is higher than the effective dose calculated in our study which is 1.54 mSv. Another similar study done by Takahashi M et al [13] found that low-dose technique (50 mAs, 120 kVp) was effective in demonstrating pathologic findings for the lung and mediastinum which agrees with the results of our study.

Similarly, Zhu X et al [14] found that there is no statistically significant difference between the quality of scans obtained at 115 mAs (routine mAs), 40 mAs and 25 mAs with the reducation in the CTDIw by 62% and 74% respectively. Hence, in their study, decreasing the mAs by approximately 65% and 78% resulted in the reduction of CTDIw by 62% and 74% respectively, whereas, in our study, decreasing the mAs by 50% resulted the reduction of CTDIvol by approximately 48%. Prasad S.R. et al [11] performed CT chest study with 50% dose reduction (220-280 mAs versus 120-150 mAs) and found that the image quality of reduced dose CT was acceptable for all weight categories. The results were similar in our study where we found that the image quality of low dose CT was acceptable for all BMI categories ($p<0.05$). The radiation dose based on CTDIw from dose reduction protocol in their study was 7.8-10.7 mSv which is significantly higher than the value found in our study. This is because the value of reduced mAs in their study was significantly higher than mAs values used in our study.

Zaporozhan J.L. et al [9] simulated the original images of chest CT obtained at 150 mAs into 10 different mAs settings from 10mAs to 100mAs and concluded that mAs could be lowered down to 60 mAs (42 eff.mAs) without a significant subjective decrease in image quality due to increased noise. However, the lowest effective mAs used in our study were 27.This value is lower than the value chosen by J. Ley-Zaporozhan et al. However, Naidich D.P. et al [15] in obtained diagnostic quality images of the lungs with setting as low as 20 mAs. Another study performed by Zwirewich C.V. et al [16] found that HRCT images acquired with 40 mAs yielded anatomic information equivalent to that obtained with 400 mAs with no significant loss of spatial resolution or image quality caused by streak artifact.

Similarly, Ambrosino et al [17] showed that HRCT of chest performed using 40 mAs and 80 mAs provided acceptable images for evaluation of most lung disorders in pediatric age group (4 months to 17 years) while Lee KS et al [18] found that the diagnostic accuracy of low dose CT (80 mAs) is acceptable for patients aged from 27 to 82 years. These results support the results obtained in our study.\Furthermore, a study by Mayo J.R. [19] found no significant difference in detection of mediastinal or lung parenchymal abnormalities with tube currents of 400 mAs, 200 mAs, 140 mAs, 80 mAs and 20 mAs. This result is similar with the result obtained in our study where we found that there is no significant difference between images acquired by using either routine or low dose protocol.

CONCLUSION

The results showed that the image quality was acceptable for all the patients scanned by reducing the effective mAs by 50%. So, we conclude that radiation dose delivered during HRCT chest can be decreased significantly by using low dose protocols without degrading the quality of the image.

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