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Automatic current selection with iterative reconstruction reduces effective dose to less than 1 mSv in low-dose chest computed tomography in persons with normal BMI

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Abstract

Most of the recent studies have used fixed tube current while few investigators use automatic current selection (ACS) with iterative reconstruction (IR) techniques to reduce effective dose (ED) to <1 mSv in low-dose chest computed tomography (LDCCT). We investigated whether image quality of lungs as produced by a fixed tube current (FTC) of 35 mAs can be maintained with ED <1 mSv produced by ACS with IR techniques in LDCCT. A total of 32 participants were included. The LDCCT was performed by a FTC 35 mAs (with a kilovoltage peak of 120 kVp) in 16 participants (Group A), and by a DoseRight ACS in 16 participants (Group B). Their images were improved by IR technique. The ED was estimated by multiplying the individual dose length product (DLP) by the dose conversion factor. The image quality was assessed by the CT number, noise levels, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR) of the regions of interest in the apex, upper lobe, and lower lobe of lung regions in the CT images. A t-test was used to evaluate the LDCCT image quality between the groups. The ED was significantly 49.2% lower in Group B than in Group A (0.71 ± 0.05 mSv vs 1.40 ± 0.02 mSv, $P<.001$). However, noise level, SNR, and CNR were not significantly different between Groups A and B, indicating the image quality was similar between two groups, or our setting parameters for DoseRight ACS with IR technique can achieve the image quality as good as obtained on the FTC 35 mAs with IR techniques. Our results suggest that the DoseRight ACS with IR technique reduces ED to lower than 1 mSv (averagely 0.71 mSv) yet maintains an image quality as good as produced by FTC 35 mAs with IR technique in normal BMI persons. The ACS setup thus is more preferable than the FTC to achieve the ALARA (as low as reasonably achievable) principle.

Abbreviations: #CT = mean CT number, ACS = automatic current selection, AEC = automatic exposure control, ALARA = as low as reasonably achievable, BMI = body mass index, CNR = contrast-to-noise ratio, $CTDI_{vol}$ = CT dose index volume, DLP = dose length, ED = effective dose, FTC = fixed tube current, IR = iterative reconstruction, LDCCT = low-dose chest computed tomography, ROI = region-of-interest, SD = standard deviation, SNR = signal-to-noise ratio, SSDE = size specific dose effect.

Keywords: automatic current selection (ACS), contrast-to-noise ratio (CNR), dose length product (DLP), effective dose (ED), fixed tube current (FTC), image quality, signal-to-noise ratio (SNR)

1. Introduction

According to National Council on Radiation Protection & Measurements (NCRP), Report No. 160 medical radiation exposure is responsible for less than 50% of human radiation exposure. Report No. 160, published by the National Council on Radiation Protection and Measurements, described that among all the sources of radiation that Americans were exposed to, the computed tomography (CT) accounted for a mere 17% of radiologic diagnostic examinations. However, the CT contributed the largest dose of radiation (49%) of all the examinations, about 1.5 mSv per person.[1] Furthermore, technological improvements in CT have increased the diagnostic accuracy and shortened scan time, leading to a significant increase in the number of CT examinations. Low-dose chest CT (LDCCT) has been increasing to assess benign diseases or screen for lung cancers. Therefore, radiation dose safety becomes more important,[2–5] and reduction of CT radiation dose is thus important in terms of maintenance of good image quality.[6]

There has been an increasing interest to use the automatic exposure control (*AEC*) technique in optimizing CT examinations in LDCCT. In respect to these problems, AEC technique facilitates automatically not only optimizing image quality but also reducing the total radiation dose to patients.[7–10] In addition, it automatically adjusts radiation dose with body mass attenuation of the image quality.[11] Although its essential aim is to maintain image quality rather than reduce radiation doses, dose savings of 20–40% are typically found for a range of adult patient scans.[7,12] Different manufacturers have developed and implemented various AEC techniques; thus, knowing how to use the AEC techniques correctly and efficiently is essential to achieving optimal image quality and minimal radiation dosage.

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The LDCCT with reduced CT radiation dose has been performed as an early lung-cancer screening.[13–17] Many different ways to lower radiation dose have optimized CT image quality of lungs. The image quality for lungs was superior or acceptable using the fixed tube current (FTC) with scanning parameters ranged widely from 120 to 80 kVp, and 20 to 50 mAs; the higher value gets the better quality, but is inevitably associated with higher radiation exposure;[7,18–22] the lower value gets the poorer quality, but is associated with less radiation exposure; these studies result in variable EDs ranged between 0.7 and 3.4 mSv which resulted in a wide range (60–600 HU) of image noise. In spite of these defects associated with the FTC technique, most of the recent studies however have used the FTC technique and only few have used the AEC technique. By the way, it is essential to mention that the iterative reconstruction (IR) technique can improve CT image quality so as to reduce radiation exposure.[23,24] The IR technique nowadays is increasingly used with both the FTC and AEC. Nevertheless, few investigators address the correlation between image quality and ED values produced by both FTC with IR technique and AEC (or ACS) with IR technique.

Based on above discussion we made the hypothesis:

1. Reduction of CT radiation dose is important in terms of maintenance of good image quality (the 1st paragraph).
2. Using the AEC techniques correctly and efficiently is essential to achieving optimal image quality with minimal radiation dosage (the 2nd paragraph).
3. The correlation between image quality and ED values produced by the FTC with IR and AEC with IR technique is not known (the 3rd paragraph).

To address above research hypotheses, we compared the ED and image quality (noise, SNR, and CNR), as well as lesion, detectability between the FTC 35 mAs with IR technique as a reference and the AEC in LDCCT. We adopted DoseRight Automatic Current Selection (ACS) with IR technique in LDCCT.

Table 1

Demographic details of 32 participants who were assigned into Groups A and B examined with Fixed Tube Current (FTC) 35 mAs and DoseRight automatic current selection (ACS) with iterative reconstruction (IR), respectively, in low-dose chest computer tomography (LDCCT, 120 kVp).

	Group A (n=16) FTC 35 mAs with IR	Group B (n=16) DoseRight ACS with IR
Age	58.88±7.61	54.75±12.42
Sex		
M	7	7
F	9	9
Height (m)	1.61±0.07	1.59±0.11
Weight (kg)	63.78±9.22	65.38±16.39
BMI (kg/m^2)	24.71±0.75	25.62±1.00
> 30	2	2
25–29.9	3	4
≤ 24.9	11	10

Scanning parameters are further shown in Table 2.
Datasets are denoted by mean±standard deviation (SD).
BMI=body mass index.

2. Materials and methods

2.1. Participants

The study was approved by the local ethics committee and the need for informed consent was waived because of the retrospective design of the study (IRB107-86-B).

Between February 2017 and June 2017, a total of 32 healthy participants (aged 30–73 years, with a mean age of 56.8±10.3 years) received routine chest examination were recruited and divided into Groups A which received the fixed tube current (FTC) 35 mAs with iterative reconstruction (IR) and Group B which received DoseRight ACS with IR technique. Their demographic details are shown in Table 1. Because this study was a retrospective approach and was limited by the regulation of our local ethics committee, we could recruit but 16 participants in each group.

2.2. LDCCT scanning parameters

Table 2 shows the scanning parameters for a FTC 35 mAs with IR (Group A) and DoseRight ACS with IR (Group B) for LDCCT. The CT image was produced in a 256-slice CT scanner (Brilliance iCT; Philips Healthcare, Cleveland, OH, USA).

2.3. Image reconstruction

For optimizing image quality of the LDCCT performed by both FTC and ACS, we applied the iDose iterative reconstruction (IR) technique (*iDose*^{4}, *Philips Healthcare*, Cleveland, OH, USA) to both techniques (Table 2). The images were reconstructed at 1.5 mm thickness and 1 mm section interval. Levels 6 and 7 images obtained with the IR technique were reconstructed with a lung convolution kernel routinely used in clinical practice.

2.4. Radiation dose assessment

Table 3 shows comparisons of the six parameters that may affect the body attenuation[25] between group A and group B.

2.4.1. *Scanning length: 1 cm on apex to end of costophrenic angle.* Effective diameter: Effective diameter is obtained from the American Association of Physicists in Medicine Task Group (TG) 204 lookup table.[26] For all patients, anteroposterior (AP) and

Table 2

Settings of low-dose chest computer tomography (LDCCT) scanning parameters employed in 256-slice CT scanner (Brilliance iCT; Philips Healthcare, Cleveland, OH, USA).

Parameter	Settings
Detection width	128×0.625 mm
Tube voltage	120 kVp
Tube current	
FTC (Fixed tube current)	35 mAs
AEC (DoseRight ACS 1-3 *(D-DOM·Z-DOM), Philips Healthcare)	15–35 mAs (min/max)
Tube rotation time	0.33 sec
Pitch	0.758
Cross-section thickness	1.5 mm
Slice interval	1 mm
Window width/level	1200/−500

* D-DOM=dynamic angular dose modulation in the *x–y* plane; Z-DOM=*z*-axis dose modulation.
ACS=automatic current selection; AEC=automatic exposure control.

Table 3

The six parameters that may affect the body mass attenuation were compared between group A and group B.

	Group A	Group B	P
Scan length (cm)	40.95±0.31	40.13±0.63	.26
Effective Diameter (cm)	26.53±5.17	26.31±6.34	.71
CTDIvol (mGy)	2.4	1.23±0.11	<.001
DLP (mGy cm)	100.30±1.43	50.44±4.80	<.001
SSED (mGy)	3.70±0.35	1.82±0.15	<.001
ED (mSv)	1.40±0.02	0.71±0.05	<.001

Datasets are denoted by mean±standard deviation (SD).
CTDIvol=CT dose index volume, DLP=dose length product, ED=effective dose, SSDE=size-specific dose estimation.

lateral (LAT) diameters were measured from axial images. An effective diameter was calculated for each of the physical anthropomorphic phantoms using the formulation described in AAPM Report 204: Eq. (1).

$$\text{Effective diameter} = \sqrt{\text{AP}\cdot\text{LAT}} \qquad (1)$$

Size specific dose effect (SSDE): The SSDE is calculated as previously described in AAPM Report 204 using the effective diameter calculated in equation Eq. (1) to look up a conversion factor to scale volume computed tomography dose index ($CTDI_{vol}$) values calculated using either a 32 cm diameter CTDI patient: Eq. (2).

$$SSDE_{patient} = CTDI_{vol}^{16\text{ or}32} \times \int_{size}^{16\text{ or}32} \qquad (2)$$

$CTDI_{vol}$ value: The value used for the SSDE calculation was obtained from the CT dose report archived with every patient CT examination.

The radiation dose of a LDCCT: It was estimated based on the $CTDI_{vol}$ and the dose length product (DLP) Eq. (3). The results of both measures were displayed and recorded on the computer of the scanner once a scan.

$$DLP(mGy\cdot cm) = CTD_{Ivol}(mGy)\cdot\text{scan lengths}(cm) \qquad (3)$$

Effective dose (ED): The ED was calculated by multiplying DLP, the individual dose report, with the dose conversion factor. The dose conversion factor (k) is 0.014 mSv/(mGycm) Eq. (4), as recommended in the American Association of Physicists' Report No. 96.[27]

$$ED = DLP(mGy\cdot cm) \times k \qquad (4)$$

2.5. Image quality assessment

The LDCCT image quality of the apex, upper lobe, and lower lobe of the lungs (window width/level=1200/−500) was assessed using ImageJ (US National Institutes of Health, Bethesda, MD, USA; http://imagej.nih.gov/ij, version 1.51p). Three areas of 4 mm^2 size where pulmonary parenchyma was encircled as regions of interest (ROIs), and the mean CT Number ($\#CT_{Lung}$) and standard deviation (SD_{Lung}) (Hounsfield Unit, HU) of the ROIs were recorded. The signal-to-noise ratio (SNR) was subsequently calculated using Eq. (5). Additionally, 3 ROIs were drawn on muscular soft tissue, and their $\#CT_{Soft\text{-}tissue}$ (HU) and $SD_{Soft\text{-}tissue}$ (HU) were recorded. Subsequently, the contrast-to-noise ratio (CNR) was calculated using Eq. (6).[28]

$$SNR = \frac{|CT_{Lung}(HU)|}{SD_{Lung}(HU)} \qquad (5)$$

and

$$CNR = \frac{|CT_{Lung}(HU) - CT_{Soft-tissue}(HU)|}{SD_{Soft-tissue}(HU)} \qquad (6)$$

2.6. Lesion and nodule assessment

The lesion detection ability was assessed for participants in the Groups A and B (n=16 each). In the CT images of each participant, lesions or nodules that were identified as noticeable in size >5 and <5 mm were counted by radiological diagnostic reports by one radiologist with 30 years of experience in reporting thoracic CT.

2.7. Statistical analysis

Statistical analysis was performed using GraphPad Prism 6 (Graphpad Software Inc., La Jolla, CA). A t test was used to compare the image quality of scans between the Groups A and B concerning (1) noise, (2) SNR, (3) CNR, and (4) ED. Moreover, one-way analysis of variance and post hoc tests were performed to determine whether any significant difference ($P<.05$) existed in ED among participants with BMI of ≥ 30, 25–29.9, and ≤ 24.9.

3. Results

3.1. Demographic information

Table 1 shows demographic details in which all data including body height, body weight, and BMI appeared to have no significant difference between Groups A and B.

3.2. Assessment of radiation dose

Table 1 indicates no difference in body height, body weight, and BMI between Groups A and B. This is in consistent with the finding of Table 3 showing there is no significant difference in the scan length and the effective diameter (cm) between groups A and B. Other 4 parameters ($CTDI_{vol}$, DLP, SSDE, and ED) which represent radiation dose in different forms show all significantly 50% lower in Group B than Group A ($P<.001$). In other words, ACS with IR is effective and efficient in reducing ED of Group A to about 50% lower as compared with that of Group B in terms of avoiding body mass attenuation of image quality.

Figure 1 demonstrates that ED was significantly reduced to 49.2% lower in Group B than that in Group A (0.71±0.05 vs 1.40±0.02 mSv, $P<.001$).

Figure 2 compares among the EDs of three different BMI cohorts in 16 participants of either Group A (a) or B (b). Group A shows no significant difference among EDs (1.42±0.09, 1.36±0.06, and 1.39±0.002 mSv) for the different BMI cohorts (BMI ≤ 24.9 kg/m^2, 25–29.9 kg/m^2, and BMI ≥ 30 kg/m^2), respectively. The FTC 35 mAs obviously produced but insignificant difference in ED ranged 1.36–1.42 mSv in three different BMI cohorts. On the other hand, Group B shows significant difference among EDs (0.52±0.11, 0.84±0.26, 1.15±0.11 mSv, $P<.05$) of the three

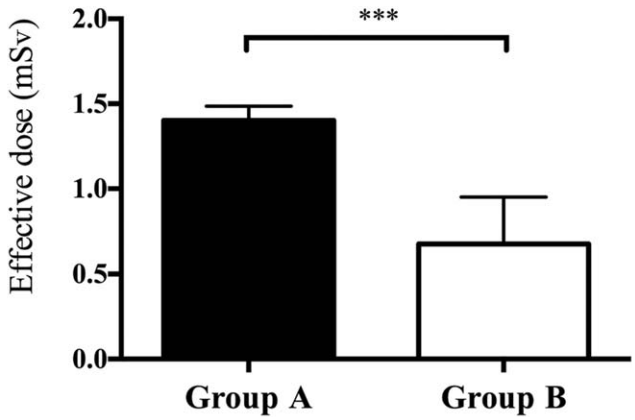

Figure 1. Comparisons of effective dose between Group A (n=16) and Group B (n=16). ***$P<.001$.

different BMI cohorts, demonstrating that the ACS-induced EDs increased significantly with greater BMI. We should, however, note that these ACS-induced EDs of the different three cohorts (Group B) were smaller than the FTC-induced EDs of these three cohorts (Group A), respectively.

3.3. Assessment of image noise

Reduction of CT radiation dose is important in terms of maintenance of good image quality. Therefore, we compared the noise values between Groups A and B (Fig. 3), in which BMI was pooled together (left two columns), $\leq$ 24.9 kg/m^2 (middle two columns), and $\geq$ 25 kg/m^2 (right two columns). The noise values for these six columns were respectively 89.22 ± 33.31 (ranging 34.08–213.02), 91.56 ± 33.44 (ranging 21.5–189.06), 86.6 ± 32.6 (ranging 34.08–213.02), 92.4 ± 25.1 (ranging 35.06–171.83), 8.4 ± 23.9 (ranging 47.16–162.77), and 93.3 ± 35.9 (ranging 38.17–189.06). They all appeared to have no significant differences as shown in Table 4, that compares of LDCCT image noises in center (C) and periphery (P) areas of the apex, upper lobe, and lower lobe of lungs between Group A and Group B.

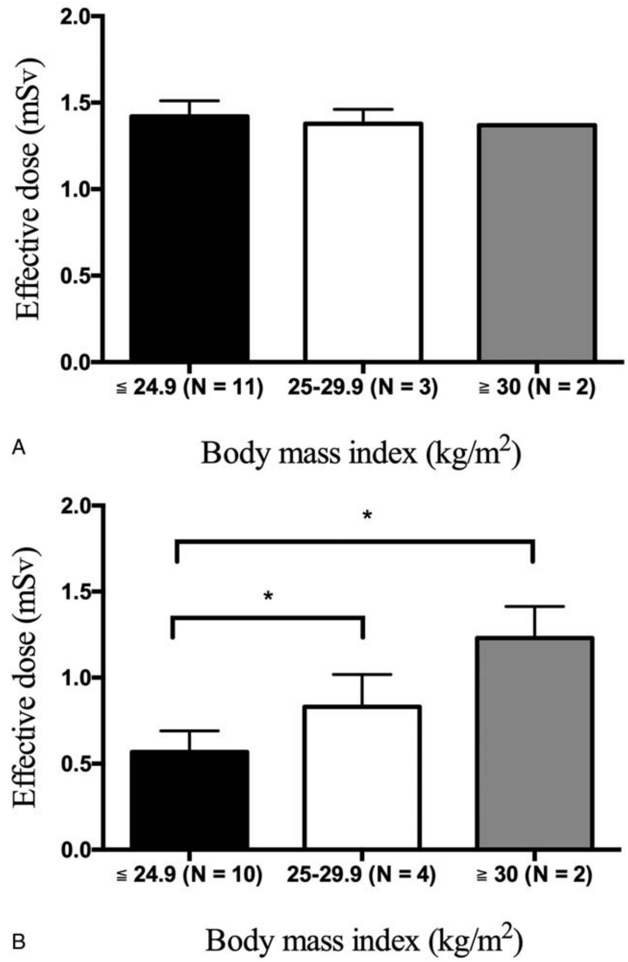

Figure 2. Comparison among the ED of three BMI cohorts (BMI $\leq$ 24.9 kg/m^2, 25–29.9 kg/m^2, and BMI $\geq$ 30 kg/m^2) in 16 participants of either Group A (A) or B (B). *$P<.05$. BMI, body mass index.

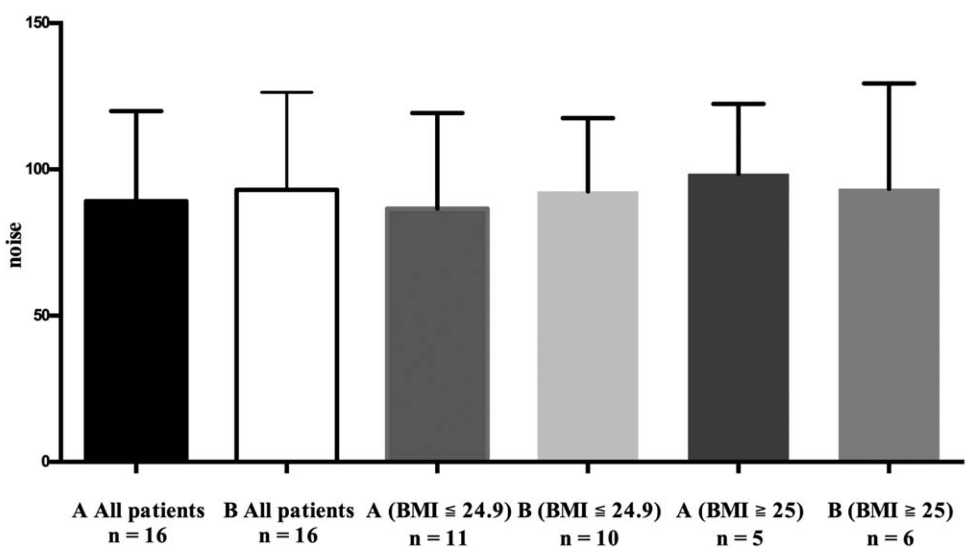

Figure 3. Comparison of the noise between Groups A and B in which BMI was pooled together (left two columns), $\leq$ 24.9 kg/m^2 (middle two columns), and $\geq$ 25 kg/m^2 (right two columns) in the cohort.

Table 4

Comparison of LDCCT image noises in center (C) and periphery (P) areas of the apex, upper lobe, and lower lobe of lungs between Group A and Group B.

	Group A		Group B		p	
	CT Number (HU)	Image Noise (HU)	CT Number (HU)	Image Noise (HU)	Group A vs Group B (CT Number)	Group A vs Group B (Image Noise)
LALL(C)	−865.32±31.25	108.10±22.37	−863.12±33.85	100.04±41.60	NS	NS
LALL(P)	−823.73±49.38	124.60±33.73	−847.82±37.21	100.40±37.22	NS	NS
LARL(C)	−862.12±37.22	103.70±11.46	−856.73±40.31	93.35±29.42	NS	NS
LARL(P)	−827.84±31.97	122.30±32.81	−843.71±46.27	106.11±29.64	NS	NS
ULLL(C)	−872.62±34.81	67.42±19.97	−873.02±37.12	71.63±22.93	NS	NS
ULLL(P)	−860.92±52.52	83.78±23.80	−856.20±41.82	94.91±28.77	NS	NS
ULRL(C)	−871.60±32.83	78.84±21.07	−877.81±25.62	87.83±31.51	NS	NS
ULRL(P)	−876.31±34.37	73.67±18.67	−876.23±25.34	90.45±28.52	NS	NS
LLLL(C)	−841.34±54.32	81.31±19.92	−851.33±42.61	82.81±27.51	NS	NS
LLLL(P)	822.82±71.94	82.06±31.73	−821.21±46.30	92.42±32.34	NS	NS
LLRL(C)	−837.91±45.21	68.15±21.81	−855.62±24.51	88.01±44.43	NS	NS
LLRL(P)	−824.51±61.12	76.81±19.72	−820.30±55.23	90.81±39.12	NS	NS
Total Mean	−839.53±129.61	89.22±33.31	−853.59±42.02	91.56±33.44	NS	NS

Datasets are denoted by mean±SD (HU).
C=center, LALL=lung apex of left lung, LARL=lung apex of right lung, LLLL=lower lobe of left lung, LLRL=lower lobe of right lung, P=peripheral, ULLL=upper lobe of left lung, ULRL=upper lobe of right lung.

Table 5

Comparison of contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) of LDCCT in Pulmonary Parenchyma of Lung Apex, Upper Lobe, Lower Lobe between Group A and Group B.

	Group A		Group B		p	
	SNR	CNR	SNR	CNR	Group A vs Group B (SNR)	Group A vs Group B (CNR)
Lung apex	8.29±1.88	9.71±2.28	9.82±3.52	10.03±4.17	NS	NS
Upper lobe	13.73±3.78	10.17±1.99	10.61±3.12	13.60±3.91	NS	NS
Lower lobe	10.99±3.04	10.77±3.28	11.23±4.22	11.51±4.90	NS	NS
Total Mean	11.01±3.69	9.88±2.39	10.71±5.12	11.70±4.60	NS	NS

Datasets are denoted by mean±SD (HU).

3.4. Assessment of SNR and CNR

For further assessment of image quality between Group A and B, Table 5 compares of SNR and CNR of LDCCT between two groups. No significant difference was found in SNR or CNR between Group A (SNR=11.01±3.69; CNR=9.88±2.39) and Group B (SNR=10.71±5.12; CNR=11.70±4.60).

3.5. Assessment of pulmonary nodule and lesion

Table 6 shows that pulmonary nodule was identified in 6 of 16 participants, in group A as well as in group B. Lesions or nodules sizes <5 mm and ≥5 mm were all able be identified in two groups.

Figure 4 presents nodules identified in the group B. There were five nodules; 3 were smaller than 5 mm; and two were 5–8 mm.

4. Discussion

The present investigation demonstrated that in LDCCT, the ED to the patients was significantly ($P<.001$) lower in DoseRight ACS Group (0.71±0.05 mSv) than in FTC 35 mAs (1.40±0.02 mSv), by 49.2% lower (Table 3, Fig. 1). However, no significant difference was noted in the noise level, SNR and CNR between Groups A (noise, 89.22±33.31 HU; SNR, 11.01±3.69; CNR, 9.88±2.39) and B (noise, 91.56±33.44 HU; SNR, 10.71±5.12; CNR, 11.70±4.60) (Tables 4 and 5); and lesions or nodules sizes < 5 mm and ≥ 5 mm were all able be identified in two groups (Table 6, Fig. 4); these findings indicated that the image quality was similar between the two groups. We conclude that the DoseRight ACS with IR setup was more preferable than the FTC 35 mAs with IR, regarding that the ACS with IR setup reduced radiation dose by 50% yet maintained image quality as produced by FTC 35 mAs with IR.

Table 6

CT findings of pulmonary nodules or lesions in Groups A and B.

Nodules size (mm)	Group A (n=16)	Group B (n=16)
Participants, nodule was found	6	6
Participants, nodule was not found	10	10
Solid nodule		
<5 mm (3.45±0.60 mm, range, 3–4.5 mm)	4	3
≥5 mm (6.93±1.43 mm, range, 5.3–8 mm)	1	2
Ground glass opacity nodule		
< 5 mm (4.26±0.46 mm, range, 4–4.8 mm)	2	1
≥ 5 mm	0	0

More than one lesion could be identified in some participants.

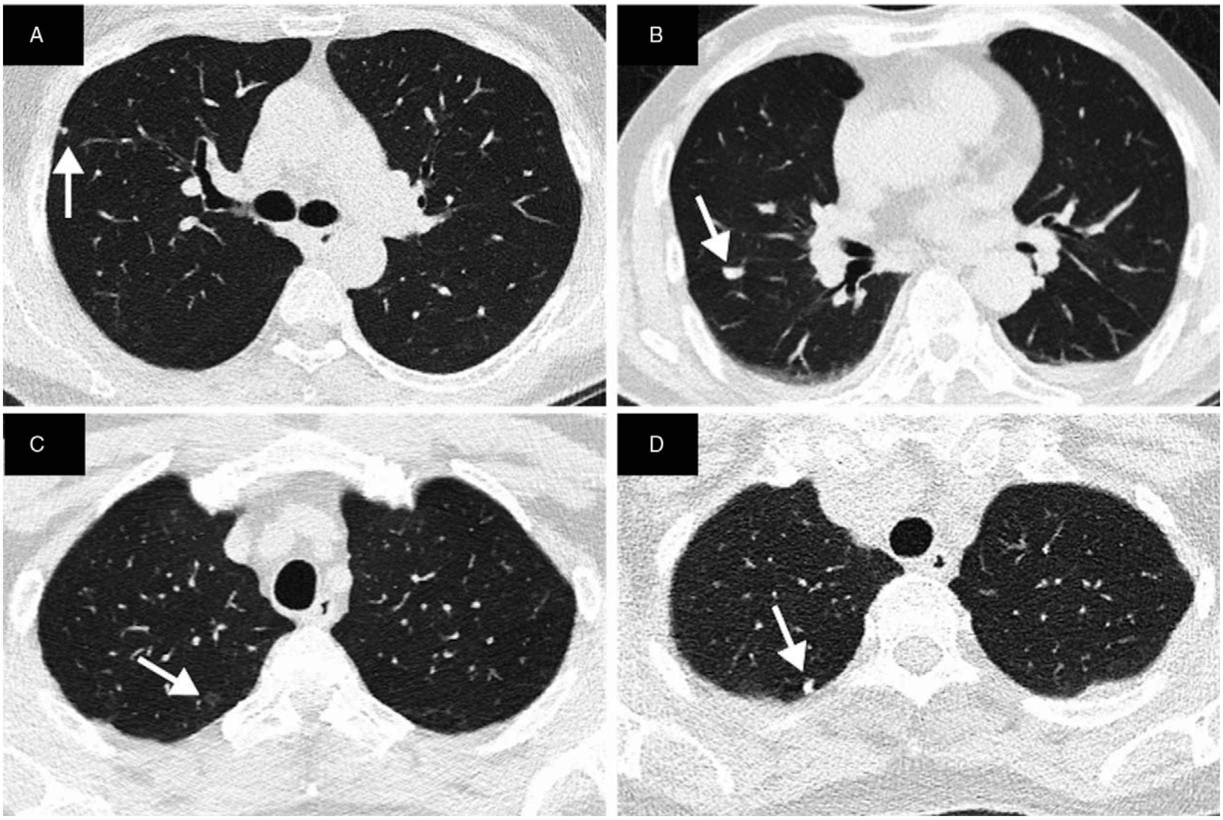

Figure 4. Chest CT images, 1.5-mm cross-sections, of the Group B show: (A) 54-year-old woman (3 mm) pleural nodule in the upper-right lung lobe; (B) 71-year-old man (>8 mm) solid nodule in the lower-right lung lobe; (C) 58-year-old man (4.8 mm) GGO in the upper-right lung lobe; and (D) 58-year-old woman (4.5 mm) nodule in the upper-right lung lobe. Arrow indicates nodule.

There is no difference in body height, body weight, and BMI (Table 1) as well as in the scan length and the effective diameter (cm) between groups A and B (Table 3), while other 4 parameters ($CTDI_{vol}$, DLP, SSDE, and ED) which represent radiation dose in different forms show all significantly 50% lower in Group B than Group A ($P<.001$). In other words, ACS with IR was effective and efficient in reducing ED of Group A to about 50% lower as compared with that of Group B in terms of avoiding body mass attenuation of image quality. In addition, ED was significantly reduced to 49.2% lower in Group B than that in Group A (0.71 ± 0.05 vs 1.40 ± 0.02 mSv, $P<.001$, Fig. 1). Findings taken together suggest that to the participants with same BMI, radiation dose produced by DoseRight ACS with IR (Group B) is about half of that with FTC 35 mAs with IR (Group A).

Examination by FTC 35 mAs with IR showed no significant difference among EDs (1.42 ± 0.09, 1.36 ± 0.06, and 1.39 ± 0.002 mSv) for the different BMI cohorts (BMI $\leq$ 24.9 kg/m^2, 25–29.9 kg/m^2, and BMI $\geq$ 30 kg/m^2), respectively (Fig. 2). On the other hand, examination by DoseRight ACS with IR showed that the resulting ED significantly increased with greater BMI (0.52 ± 0.11, 0.84 ± 0.26, 1.15 ± 0.11 mSv, $P<.05$, Fig. 2). These findings indicated the FTC produced only constantly higher EDs at 1.42–1.39 mSv for the three different BMI cohorts, while the DoseRight ACS produced proportionally greater EDs at 0.52, 0.84, 1.15 mSv due to greater BMI cohorts (values). We should, however, note that these DoseRight ACS-induced EDs (Group B) were smaller than the FTC-induced EDs (Group A), respectively. In conclusion, the Doseright ACS with IR was more advantageous than the FTC with IR for the LDCCT, because the ACS is effective and efficient in reducing ED of Group A to about 50% lower (Fig. 1) in terms of avoiding body mass attenuation of image quality.

The FTC with scanning parameters commonly ranged widely from 80 to 120 kVp, and 20 to 50 mAs; the higher value gets the better quality, but is inevitably associated with higher radiation exposure.[7,18–22] To standardize the ED and its resulting image quality produced by DoseRight ACS, the present investigation took the FTC 35 mAs-produced ED and its resulting image quality as references. We adopted FTC 35 mAs at our hospital because 35 mAs are about the mid values between 20 and 50 mAs, and we found that FTC 35 mAs produced relatively better image quality (Fig. 4; Tables 4–6). Therefore, we set the DoseRight ACS at 15–35 mAs as shown in Table 2. The present investigation first characterized and then compared the ED and image quality resulted from the FTC 35 mAs (Group A) and ACS (Group B). The present findings are the first demonstrating that the ED was significantly ($P<.001$) lower in DoseRight ACS Group (0.71 ± 0.05 mSv) than in FTC 35 mAs Group (1.40 ± 0.02 mSv), by 49.2% lower (Fig. 1; Table 3).

We are also the first demonstrating that the significant lowering of ED was accompanied with no significant difference in noise level, SNR, and CNR between Groups A (noise, 89.22 ± 33.31 HU; SNR, 11.01 ± 3.69; CNR, 9.88 ± 2.39) and B (noise, 91.56 ± 33.44 HU; SNR, 10.71 ± 5.12; CNR, 11.70 ± 4.60) (Tables 4 and 5). These findings indicated image quality is similar between the two groups. The similar image quality between the two groups was further supported by findings that detection ability of nodules or lesions less or greater than 5 mm were subjectively observed in the two groups (Table 6, Fig. 4). These findings clearly explain that reduction of CT radiation dose by ACS is important in terms of maintenance of good image quality.

Identification of lung lesions or images in the literature depends mostly on subjective observations by the radiologist, while objective data to judge image quality is relatively lacking. One advantage of the present investigation provided, in addition to the subjective observations, the objective data on the ED and image quality produced by the DoseRight ACS and the FTC 35 mAs (Tables 4 and 5). Nevertheless, whether our ACS results of lowering ED by 50% with the noise level as good as that of FTC 35 mAs (89.22 ± 33.31 HU vs 91.56 ± 33.44 HU) have achieved the ALARA (as low as reasonably achievable) principle is not known. Our objective data relating ED and image quality may facilitate future studies to achieve this principle.

Although the ACS setup is more preferable than the FTC to achieve the ALARA principle, we set the DoseRight ACS at 15–35 mAs as shown in Table 2. However, Fig. 2 indicated the ACS did produce ED >1 mSv (1.15 mSv) for BMI ≥ 30 kg/m^2. Whether reduction of this current range can further achieve the ALARA principal or not remains to be addressed.

Our findings indicated the DoseRight setup was more preferable than the FTC 35 mAs, regarding that ACS with IR setup reduced radiation dose by about 50% yet maintained image quality as produced by FTC 35 mAs with IR. The study certainly did not demonstrate this definitively. The study population was small comprising 32 persons, 16 persons in each group, because the study was retrospective and limited by ethics committee to just 16 patients per group. A cohort study therefore is not the better design to address this type of investigation. Nevertheless, we thought the finding is very preciously interesting. We hope it can be published as soon as possible and we like to share it with investigators worldwide for further studies.

Three limitations in our study must be considered. First, the study population was small comprising 32 patients. Second, because the CT scanning delivers radiation, it is not allowed to re-examine the same participant by different parameters for the comparison of effects between two different parameters. Therefore, the CT scanning results obtained from individual participants could not be compared with different parameters. Third, the lung nodules in the CT images were confirmed subjectively by two radiologists but without confirmation by a histopathologist.

5. Conclusions

The DoseRight setup was more preferable than the FTC 35 mAs, regarding that ACS with IR setup reduced radiation dose by about 50% yet maintained image quality as produced by FTC 35 mAs with IR. ACS with IR even reduces effective dose to <1 mSv in LDCCT in persons with normal BMI. These data may help future studies to achieve the ALARA principle.

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