


Image quality and clinical usefulness of automatic tube current modulation technology in female chest computed tomography screening

Cheng Li, MD^a , Lin Qi, PhD^a, Yusheng Zhang, MD^a, Feng Gao, MD^a, Xiu Jin, MD^a, Lukai Zhang, MD^a, Huan Tang, MD, Ming Li^{a,b,*} 

Abstract

The study was aimed to evaluate the image quality and radiation dose during female chest computed tomography (CT) screening using organ-based tube current modulation technology X-ray combined applications to reduce exposure (XCARE).

Five hundred sixty female individuals undergoing chest CT scan were prospectively enrolled and divided into 4 groups based on body mass index (BMI). Then they were randomly and equally divided into control and experimental subgroup and respectively accepted conventional low-dose and XCARE technology spiral CT scan with same parameters. Signal-to-noise ratio and contrast-to-noise ratio were calculated. The quality of the images was evaluated by 2 radiologists using a 5-point scale.

Among experimental subgroups of the 4 BMI groups, Signal-to-noise ratios, CT dose index of volume, dose-length product, effective dose, and contrast-to-noise ratio all displayed significant differences, as well as in control subgroups ($P < .001$). Both the experimental and control subgroups showed an increasing trend in radiation dose with the increasing of BMI. Parameters of image quality and radiation dose displayed no significant differences between control and experimental subgroups in the 4 groups. In multiple linear regression analysis, age and scanning protocol were not associated with radiation dose ($P > .05$), while BMI was significantly associated with increased CT dose index of volume ($P < .05$). The display of the lesions for the patients in the control and experimental subgroups of the 4 groups with different BMIs exhibited no statistically significant difference.

The same image quality and radiation dose can be obtained using XCARE technology compared to conventional chest CT scans, which can be used regularly in female patients.

Advances in knowledge: Using automatic tube current modulation technology to reduce exposure in breast. In this study, we sought a radiation protection method for sensitive tissue in chest CT screening.

Abbreviations: BMI = body mass index, CNR = contrast-to-noise ratio, CT = computed tomography, CTDI_{vol} = CT dose index of volume, ED = effective dose, SAFIRE = Sinogram affirmed iterative reconstruction, SNR = signal-to-noise ratio, XCARE = X-ray combined applications to reduce exposure.

Keywords: breast, computed tomography, dose-saving technique, radiation, X-ray combined applications to reduce exposure

1. Introduction

Currently, low-dose helical computed tomography (CT) screening for lung cancer has been widely accepted.^[1,2] However, with conventional chest CT scans, the mammary gland is unavoidably exposed to direct radiation. Recently research shows that digital

mammography average glandular dose is the same range as glandular tissue dose for lung cancer screening CT exams.^[3] The mammary gland is highly sensitive to radiation.^[4] Therefore, reducing direct radiation of the breast is extremely important for the prevention of breast cancer and breast diseases in women

Editor: Wen-Wei Sung.

CL and LQ contributed equally to this work.

This work was supported by the National Natural Science Foundation of China (grant no. 61976238), the Shanghai Hospital Development Center Program (grant no. SHDC22015025), the Health Commission of Shanghai, Wise Information Technology, Major Program of Medical Imaging (grant no. 2018ZHYL0103).

The authors have no funding and conflicts of interest to disclose.

Supplemental Digital Content is available for this article.

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

^a Department of Radiology, Huadong Hospital Affiliated to Fudan University, ^b Institute of Functional and Molecular Medical Imaging, Fudan University, Shanghai, China.

* Correspondence: Ming Li, Department of Radiology, Huadong Hospital, Building 8 4th Floor, 221 West Yan'an West Road, Shanghai, China (e-mail: minli77@163.com).

Copyright © 2020 the Author(s). Published by Wolters Kluwer Health, Inc.

This is an open access article distributed under the Creative Commons Attribution License 4.0 (CCBY), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Li C, Qi L, Zhang Y, Gao F, Jin X, Zhang L, Tang H, Li M. Image quality and clinical usefulness of automatic tube current modulation technology in female chest computed tomography screening. *Medicine* 2020;99:33(e21719).

Received: 22 March 2019 / Received in final form: 30 April 2020 / Accepted: 11 July 2020

<http://dx.doi.org/10.1097/MD.00000000000021719>

who undergo a CT scan during a physical or follow-up examination.

The X-ray combined applications to reduce exposure (XCARE) scan sequence is option of Siemens application. XCARE uses exposure technology that involves an automatically adjusted tube current. That is, when the tube is rotated to the position above the body, the tube current is reduced to lower the radiation dose to the sensitive area, and when the tube is rotated to the back side of the body, the tube current is adjusted back to the normal level. The lowest tube current is reduced to 25% of the average, which can effectively reduce the radiation dosage to the sensitive area of patient.^[5]

This study aimed to apply the XCARE technology to female CT screening for lung disease and to explore the application value of the XCARE technology in female lung screening compared with regular chest CT scan.

2. Patients and methods

This study was approved by the Institutional Review Board of our hospital and informed consent was sought from all individuals participating in the study.

2.1. Patient selection

From February 2018 to August 2018, we prospectively assessed 608 consecutive female participants referred to our department for chest CT screening. Exclusion criteria included history of total breast resection ($n=6$), severe respiratory symptoms that interfered with the process of CT scan ($n=22$), fail to lie on their back with arms raised over the head ($n=14$), declined to participate ($n=6$). Finally, a total of 560 patients were enrolled in our study. Patient height and weight were recorded before CT scan to calculate body mass index ($BMI = \text{body weight}/\text{height}^2$ [kg/m^2]). All the participants were divided into the following 4 groups based on BMI: Group 1, $BMI < 25$; Group 2, $BMI \geq 25$ and < 28 ; Group 3, $BMI \geq 28$ and < 32 ; Group 4, $BMI \geq 32$. Then each group of participants were randomly and equally divided into experimental and control subgroup (Fig. 1).

2.2. Chest CT scan protocol

All participants were scanned with a Somatom Definition Flash CT (Siemens Healthineers, Germany) instrument, and the scan range covered the entire lung, from the level of the lung apex to the liver dome. Patients were required to hold their breath at the end of deep inhalation during the examination. For all the participants, the underwear and other metal objects were removed before the scanning procedure.

The scanning parameters were as follows: for the experimental group, 100 kV and CARE Dose 4D, with 5-mm and 1-mm layer thickness; the collimator was 128×0.6 mm; pitch 0.6; option value of sinogram affirmed iterative reconstruction (SAFIRE) was 2; the convolution kernel of the pulmonary window I70f was very sharp; the mediastinal window of I31 was medium smooth; none IV contrast and the scanning program that included the XCARE function to protect sensitive organs was selected for the scanning procedure.^[6] For the control group, all the conditions were identical to those for the experimental group except that the XCARE function was not used (Fig. 2).

2.3. Image quality assessment

The 5-mm layer thickness axial images were selected for each patient. The left pectoralis major on the apex level, the descending aorta on the carina level, and the left atrium were selected in the mediastinal window (width, 400 HU; level, 40 HU) as the region of interest to measure and record the average CT HU value and background noise (standard deviation [SD]). The circular region of interest was 200 mm^2 . Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated. $CNR = (\text{average CT HU value of descending aorta} - \text{average CT HU value of same layer muscle}) / \text{background noise}$.^[7]

All patient and scanner demographic data were removed and the analysis of images was independently performed by 2 senior radiologists with a double-blind method. The clarity of the display of the mediastinum, great vessels, pleura, chest wall soft tissue, lung segment, and sub-segmental bronchi, as well as the details of anatomical structures, particle size, and artifacts were primarily observed. A 5-point scale was used as the criteria to subjectively assess the image quality^[4]: 5, anatomic details and lesions were clearly shown, and the image could be simply and clearly evaluated; 4, the anatomical structures and details as well as the lesions were somewhat clearly shown, and the image was evaluable but was not particularly good; 3, most of the anatomical structures and lesions could meet the diagnostic requirements, but a small number of images could not be evaluated; 2, the display of the anatomical structures and lesions was not clear, and the details could not be observed; 1, the anatomical structures and lesions were too vague for a diagnosis. A score of 3 and above can meet the diagnostic requirements.

The anatomical details were associated with the analysis of the mediastinal window and lung window (width, 1500 HU; level, -700 HU), including the ability to display the lesion morphology, size, and boundary. The lesions (normal, ground-glass nodules, fibrous cord, calcification, empty cavity, and lesion of thymus) in each patient were evaluated by 2 radiologists.

2.4. Radiation dose

The CT dose index of volume ($CTDI_{vol}$) and dose-length product (DLP) for each participant were recorded. The $CTDI_{vol}$ reflects the average dose throughout the entire scan volume, while the DLP was used to evaluate the total radiation dose for the participant during a full CT scan.^[8,9] DLP was converted to effective dose (ED) in millisieverts (mSv) by multiplying it by the thoracic conversion factor of $0.0144 \text{ mSv mGy}^{-1} \text{ cm}^{-1}$.^[10]

2.5. Statistical analysis

Statistical analysis was carried out by SPSS 22.0 software (IBM SPSS Statistics, Armonk, NY) and GraphPad Prism (Prism for Windows, Version 7.0a; Graph-Pad Software, Inc., La Jolla, CA). Values were described with either mean \pm SD or median with interquartile range after testing the normality of variables using Shapiro–Wilk test. Parameters among the 4 groups were compared by Kruskal–Walls test. The average CT HU value, the noise (SD), SNR, CNR, $CTDI_{vol}$, and DLP for the 2 subgroups of images were compared with the Mann–Whitney *U* test or Dunnett *t*-test for 2 independent samples. The agreement of the scores obtained from the evaluation by different physicians was determined using the *Kappa* test, for which can be interpreted as follows: ≤ 0 , no agreement; 0.01 to 0.20, as none

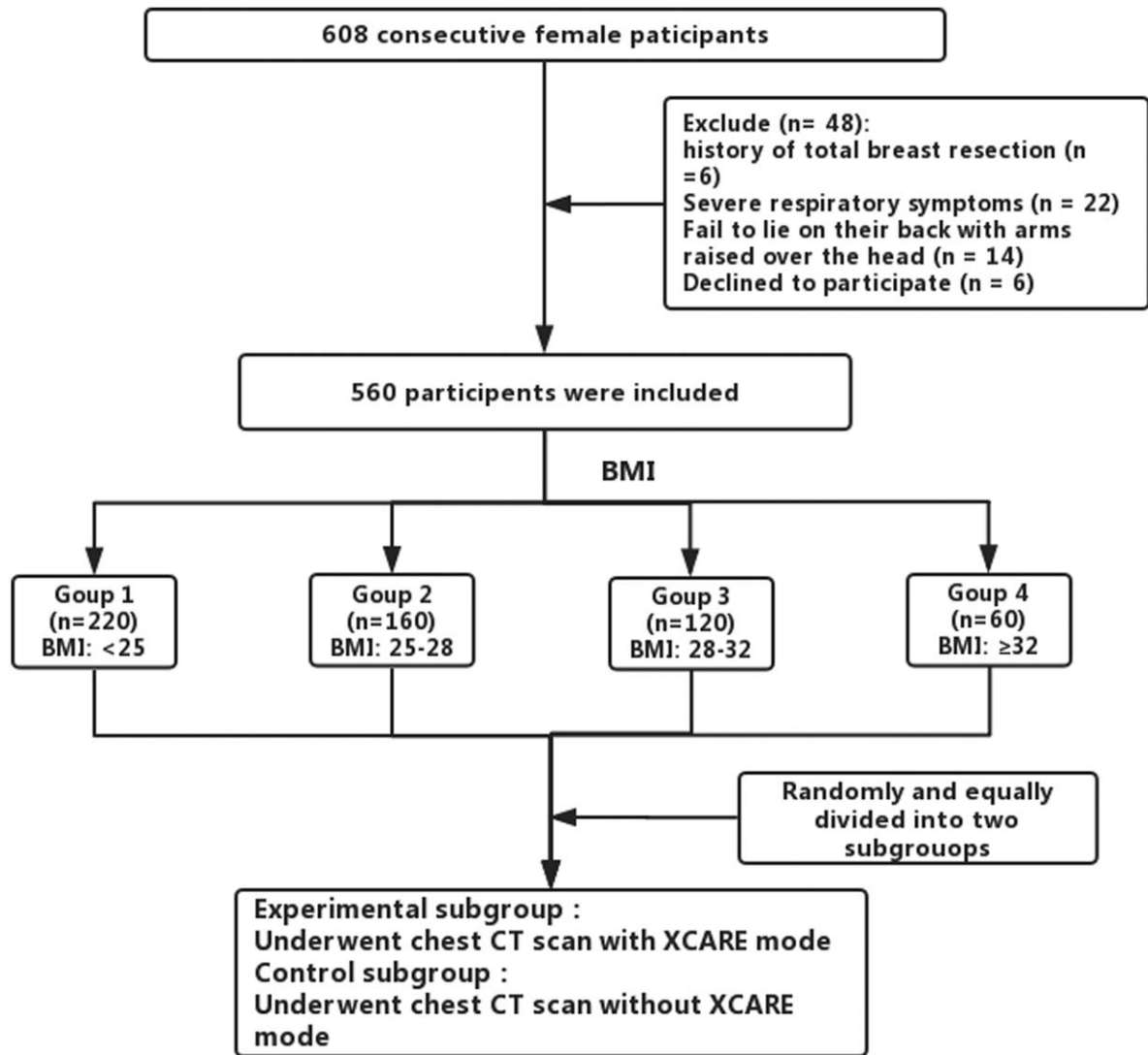


Figure 1. Flowchart of research participants examined by chest CT scan. BMI=body mass index, CT = computed tomography.



Figure 2. The quality of all the images met the diagnostic requirements. (A) Displays a case in which the XCARE technology was not used, while (B) shows a case with the use of the XCARE technology. XCARE = X ray combined applications to reduce exposure.

Table 1
Patient characteristics, radiation dose, and image quality in the 4 groups.

	Total	Group 1	Group 2	Group 3	Group 4	P
Patients n [%]	560	220 [39.3]	160 [28.6]	120 [21.4]	60 [10.7]	.26
Age (yr)	40 (36–62)	49 (36–66)	48 (33–63)	47 (35–58)	52 (41–60)	<.001
BMI (kg/cm ²)	26 (22.8–29.4)	22.1 (20.5–23.7)	26.3 (25.7–27.2)	30.2 (29.0–31.1)	33.1 (32.3–33.7)	<.001
CTDI _{vol} (mGy)	6.3 (5.7–8.0)	5.5 (5.1–5.9)	6.5 (6.0–7.1)	8.4 (7.8–8.8)	10.1 ± 0.7	<.001
DLP (mGycm)	151.5 (129.4–192.1)	126.6 (115.1–137.3)	158.85 (143.7–173.2)	220.4 (181.1–259.5)	277.2 ± 43.0	<.001
ED (mSv)	2.1 (1.8–2.7)	1.8 (1.6–1.9)	2.22 (2.01–2.4)	3.1 (2.5–3.6)	3.9 ± 0.6	<.001
Image quality						
SNR1	6.23 (5.06–7.56)	6.85 (5.82–7.98)	7.03 ± 1.87	4.83 ± 1.00	6.13 ± 1.63	<.001
SNR2	4.77 (3.91–6.19)	4.65 (4.01–5.60)	7.09 ± 1.71	3.95 ± 0.64	4.13 ± 0.84	<.001
SNR3	4.80 (4.01–6.52)	4.37 (3.86–5.42)	8.34 ± 2.30	4.16 ± 0.56	4.74 ± 0.96	<.001
CNR	2.84 (1.74–4.03)	3.78 (2.88–4.64)	2.80 (1.84–4.25)	1.24 (0.61–1.96)	2.51 ± 0.91	<.001

Values were described with either mean ± standard deviation (SD) or median with interquartile range (IQR) after testing the normality of variables using Shapiro–Wilk test.

BMI = body mass index, CTDI = CT dose index of volume, DLP = dose-length product, ED = effective dose, SNR = signal noise ratio, SNR1 = SNR of the left pectoralis major on the apex level, SNR2 = SNR of the descending aorta on the carina level; SNR3: SNR of the left atrium.

to slight; 0.21 to 0.40, as fair; 0.41 to 0.60, as moderate; 0.61 to 0.80, as substantial; 0.81 to 1.00, as almost perfect agreement. Multiple regression analysis was used to determine the independent predictors of radiation dose (CTDI_{vol}), and Pearson correlation analysis was performed between the predictor and radiation dose. A *P*-value of less than .05 was considered significant.

3. Results

3.1. Descriptive statistics and image quality in 4 groups

Descriptive statistics of the parameters of 4 groups were summarized in Table 1. All the 560 female participants successfully completed the chest CT scan (age, 48 ± 15.0 years; BMI, 26.2 ± 4.2 kg/cm²). The ED was 2.4 ± 0.8 mSv. No significant difference was found with respect to age among the 4 groups. But CTDI_{vol}, DLP, ED, SNRs, and CNR were significantly different among them (*P* < .001). CTDI_{vol}, DLP, and ED showed an increasing trend with the increase of BMI.

Among experimental subgroups of the 4 BMI groups, SNRs at different levels, CTDI_{vol}, DLP, ED, and CNR all displayed significant differences, as well as that in control subgroups (*P* < .001). Both the experimental and the control subgroup obtained the maximum SNR value in group 2 (BMI, 25–28) (Fig. 3A–C), and the maximum CNR value in group 1 (BMI < 25). In control subgroup, both of the BMI < 25 and BMI 25 to 28 groups could obtain higher CNR values, while in experimental subgroup, there was no advantage of CNR between BMI 25 to 28 (group 2) and BMI > 32 (group 4) (Fig. 3D). Both the experimental and control subgroups showed an increasing trend in radiation dose with the increasing of BMI (*P* > .001) (Fig. 3E and F).

3.2. Image quality and radiation dose in subgroups

Table 2 summarizes the average CT values, the noise, and SNR at different levels, as well as CNR in control and experimental subgroups at different BMI levels, which were not significantly different from each other. The radiation doses including CTDI_{vol} and DLP for the subgroups were shown in Table 3. There were no significant differences between control and experimental subgroups in 4 groups.

The scores reflecting the image quality for the control and experimental subgroups in the 4 groups with different BMIs were showed in Table 4, and none of differences between the experimental and control subgroups were statistically significant (*P* > .05). Good inter-observer agreement was found for Group 1, and moderate inter-observer agreement was found for Group 2, 3, and 4. Furthermore, the quality of all the images met the diagnostic requirements (Fig. 2). In multiple linear regression analysis, age ($\beta = 0.001$, 95% confidence interval, -0.01 to 0.00 , *P* > .05) and scanning protocol ($\beta = 0.02$, 95% confidence interval, -0.12 to 0.15 , *P* > .05) were not associated with radiation dose, while BMI was significantly associated with increased CTDI_{vol} ($\beta = 0.34$, 95% confidence interval, 0.32 – 0.35 , *P* < 0.05) (Supplement Table, <http://links.lww.com/MD/E702>). Correlation was significant between BMI and CTDI_{vol} (correlation coefficient, 0.863, *P* = .000).

3.3. Number of detected lesions

The display of the lesions for the patients in the control and experimental subgroups of the 4 groups with different BMIs exhibited no statistically significant difference (Table 5). In the control group, 3 cases were diagnosed with ground glass lesions of 3 to 6 mm, in 2 cases of which the lesions were in the right upper lung lobe, and the lesion was in the left lung lobe in 1 case. In the experimental group, 4 cases were diagnosed with ground glass lesions of 3 to 5 mm; in 2 cases, the lesions were in the right upper lobe, and in 1 case each, the lesion was in the right middle lobe and the left upper lobe.

4. Discussion

With consideration of the extremely radiosensitive glandular tissue in the female breast, dose saving algorithms have to be applied, if possible. In chest CT examinations, breasts are usually not diagnostically targeted, but they receive a considerable amount of unnecessary radiation dose.^[11] Previous studies have shown that the tissues in the mammary gland are highly sensitive to radiation, and the irradiation of these tissues is thus more likely to cause tumors than the irradiation of other organs.^[12,13] One of the main goals is to minimize the exposure of the breast to radiation. The increasing number of diagnosed breast cancer

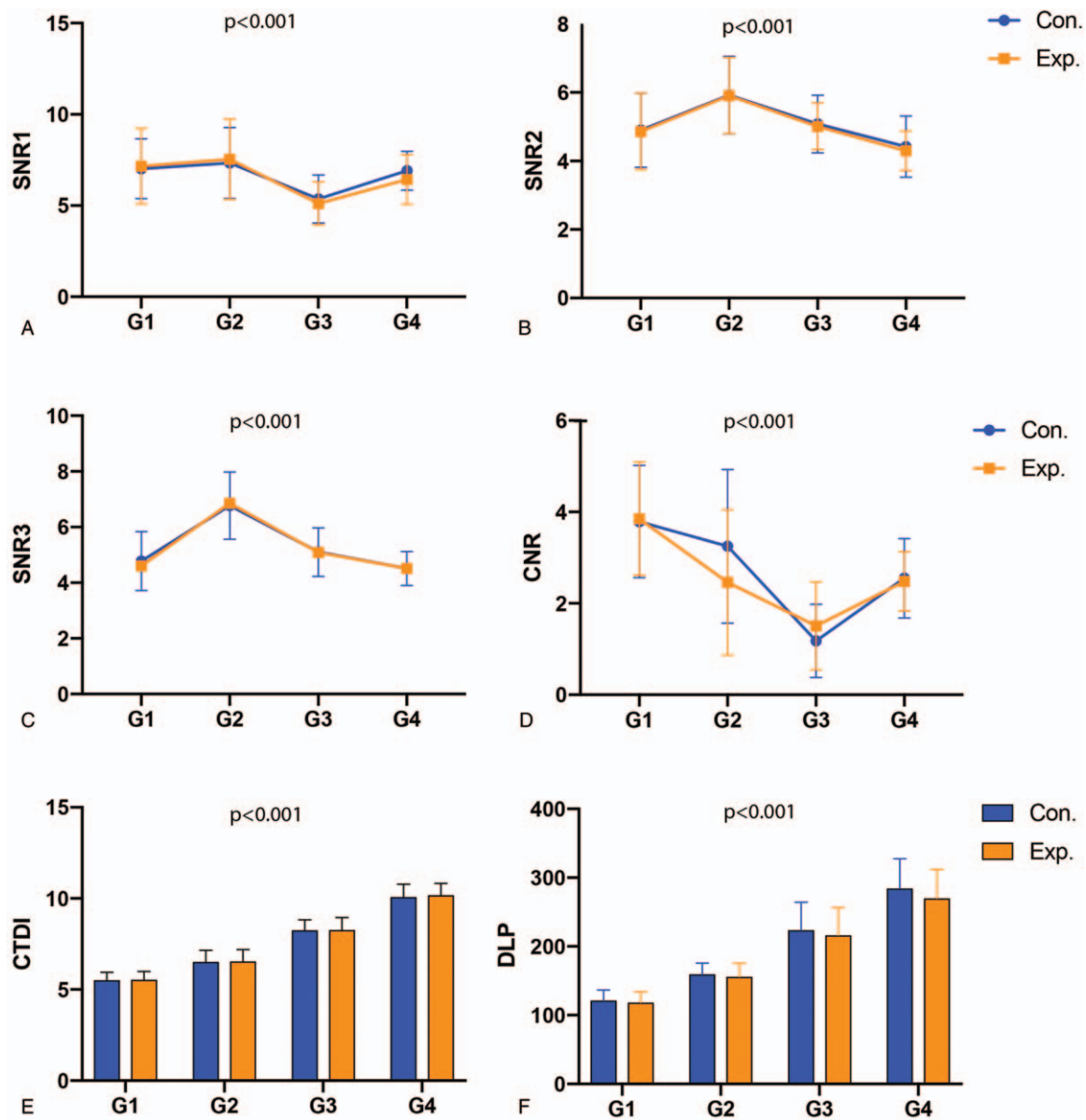


Figure 3. Among experimental subgroups of the 4 BMI groups, SNRs at different levels, $CTDI_{vol}$, DLP, ED, and CNR all displayed significant differences, as well as that in control subgroups. Both the experimental and the control subgroup obtained the maximum SNR value in group 2 (A–C), and the maximum CNR value in group 1 (BMI <25). In control subgroup, both of the BMI <25 and BMI 25 to 28 groups could obtain higher CNR values, while in experimental subgroup, there was no advantage of CNR between BMI 25 to 28 (group 2) and BMI >32 (group 4) (D). Both the experimental and control subgroups showed an increasing trend in radiation dose with the increasing of BMI ($P > .001$) (E and F). BMI = body mass index, $CTDI$ = CT dose index of volume, DLP = dose-length product, SNR = signal noise ratio, SNR1 = SNR of the left pectoralis major on the apex level, SNR2 = SNR of the descending aorta on the carina level; SNR3: SNR of the left atrium.

cases is a cause of concern. A number of studies evaluated the influence of medical radiation exposure on future occurrence of malignant tumors in women who were exposed to high radiation doses due to multiple radiation examinations or treatment by radiotherapy.^[14–16] However, the advantages of lung CT examination in revealing small pulmonary lesions has gradually become an important tool in physical examinations. In the conventional chest CT scanning procedure, the direct exposure of the breast to radiation is not avoidable, and the breast is not the target organ in lung CT screening; therefore, it is self-evident that the biological effect of frequent examinations or large doses of radiation might be a potential cancer risk.^[13]

Automatic tube-current modulation techniques have been widely used in CT examination.^[17] Spiral CT, as the name suggests, is the mode in which the tube and the detector rotate around the body, and the X-ray emitted from the tube arrives at the receiving detector through the body to obtain the image information after photoelectric conversion. Some vendors have developed organ-based tube current modulation techniques to protect superficial radiosensitive organs, such as breasts. It has been reported that with the application of organ-based tube current modulation (X-CARE, Siemens Healthcare), the tube current (mA) is reduced by 80% with a corresponding increase in the posterior region, thereby reducing the risk of breast

Table 2
Comparison of the average CT values, the noise (standard deviation, SD), the signal to noise ratio (SNR) and contrast to noise ratio (CNR) between control subgroup and experimental subgroup in the 4 groups.

Group		Left pectoralis major on the apex level			Descending aorta on the carina level			Left atrium			CNR
		Ave. HU	Noise	SNR	Ave. HU	Noise	SNR	Ave. HU	Noise	SNR	
Group 1 (n=220)	Con. (n=110)	61.54±9.30	9.11±1.90	7.02±1.64	39.34±3.48	8.35±1.60	4.90±1.08	36.59±2.94	7.99±1.65	4.78±1.06	3.79±1.23
	Exp. (n=110)	62.60±9.57	9.23±2.06	7.16±2.07	38.96±3.49	8.34±1.58	4.86±1.12	35.97±3.02	8.17±1.66	4.60±1.07	3.85±1.24
	P	.406	.659	.576	.416	.976	.827	.125	.428	.210	.741
Group 2 (n=160)	Con. (n=80)	60.99±7.88	8.77±2.06	7.33±1.95	39.64±5.15	6.85±1.07	5.92±1.13	41.40±5.66	6.21±0.83	6.77±1.21	4.26±1.48
	Exp. (n=80)	59.12±8.18	8.38±2.22	7.54±2.20	40.44±4.29	7.00±1.02	5.91±1.11	42.13±5.59	6.26±0.85	6.85±1.27	4.17±1.44
	P	.143	.251	.510	.287	.355	.950	.412	.665	.719	.686
Group 3 (n=120)	Con. (n=60)	51.83±8.90	9.95±1.57	5.36±1.32	38.77±3.93	7.77±1.05	5.08±0.84	38.81±3.87	7.76±1.15	5.10±0.87	1.27±0.90
	Exp. (n=60)	49.41±7.81	9.94±1.74	5.11±1.18	39.31±3.56	7.95±0.99	5.01±0.68	38.78±4.40	7.78±1.00	5.09±1.00	1.51±0.96
	P	.115	.991	.287	.426	.328	.615	.968	.906	.921	.156
Group 4 (n=60)	Con. (n=30)	62.42±8.10	9.12±1.13	6.91±1.06	36.71±3.31	8.57±1.48	4.42±0.89	38.88±1.96	8.75±1.15	4.51±0.61	2.55±0.87
	Exp. (n=30)	58.09±9.03	9.19±1.12	6.43±1.36	37.52±3.50	8.81±0.86	4.30±0.58	38.98±1.67	8.88±1.48	4.51±0.76	2.48±0.95
	P	.056	.81	.126	.357	.432	.553	.833	.705	.969	.766

Ave.HU=average CT HU of region of interest, CNR=contrast-to-noise ratio, Con.=control subgroup, Exp.=experimental subgroup, SNR=signal-to-noise ratio.

diseases.^[5,18,19] Lungren MP et al^[20] reported that, with organ-based tube current modulation in adult anthropomorphic phantom, breast dose can be reduced by 17% to 47% with no detrimental effect on image quality. Wanyi Fu et al^[16] reported that organ-based tube current modulation reduced breast dose by 38.6%±8.1% in 13 female anthropomorphic computational phantoms. However, there is still a lack of clinical research on the application of organ-based tube current modulation technology in female patients. Similar to the results of previous phantom researches, in our study, the objective parameters and subjective evaluation of the image quality, as well as the radiation dose for the experimental group after using the XCARE technology revealed no significant difference compared with the control group. Because the chest CT scan protocol automatically adjusts the tube voltage based on the patient's BMI, this study was based on a BMI stratification analysis and we concluded that there were no statistically significant differences in image quality and radiation dose between the experimental and control groups within the same BMI range.

Thus, the tube current is reduced for tube position, where x-rays pass the patient from anterior to posterior, to reduce the direct exposure of radiosensitive organs. To maintain

image quality, the tube current is increased for the remaining projections (posterior to anterior) to get the same milliamperere per rotation, the shaded area indicates the region for very low-dose X-ray emission and the tube current is decreased. Considering the radiation doses distributed non-uniformly in the scan region, exposure to breast areas remain low compared to other areas of the body.

It indicated that the application of the XCARE technology for lung CT screening could reduce the irradiation of the breast while maintaining the same image quality in the lung CT scan. In the subjective rating, the display of the lung structure and lesions also showed no difference between the 2 groups of images, and the images of both groups could reveal the lesions well. Both the control and experimental groups exhibited a good performance in the detection and details of small lesions, with clear anatomical structures of the lesions, including fibrous stripes, calcification, and bullous emphysema, and the difference was not statistically significant, thus meeting the diagnostic requirements.

One of the limitations of our study is that no specific instrument is used to measure the radiation dose received by the

Table 3
Comparison of the radiation dose between the subgroups.

Group		CTDI (mGy)	DLP (mGy)
Group 1: BMI: 18–25	Con.	5.51±0.43	121.28±15.38
	Exp.	5.53±0.46	118.21±15.53
	P	.509	.604
Group 2: BMI: 25–28	Con.	6.52±0.63	159.47±16.27
	Exp.	6.54±0.66	155.86±19.35
	P	.413	.082
Group 3: BMI: 28–32	Con.	8.25±0.58	223.50±40.49
	Exp.	8.26±0.69	216.33±40.01
	P	.350	.763
Group 4: BMI: >32	Con.	10.08±0.71	284.45±43.24
	Exp.	10.18±0.65	270.03±42.17
	P	.666	.741

BMI=body mass index, Con.=control subgroup, CTDI=CT dose index of volume, DLP=dose-length product, Exp.=experimental subgroup.

Table 4
Comparison of the subjective rating for the images between the 2 subgroups, the control group and the experimental group, in the 4 BMI groups. The inter-observer consistency for each BMI subgroup (control/experimental group in total) is listed in the right column.

Group		Score A	Score B	Kappa
Group 1	Con.	4.81±0.39	4.81±0.39	0.752 (P<.001)
	Exp.	4.83±0.38	4.84±0.37	
	P	.728	.598	
Group 2	Con.	4.40±0.49	4.38±0.49	0.606 (P<.001)
	Exp.	4.54±0.50	4.45±0.50	
	P	.082	.338	
Group 3	Con.	4.52±0.50	4.52±0.50	0.734 (P<.001)
	Exp.	4.57±0.50	4.57±0.50	
	P	.586	.586	
Group 4	Con.	4.27±0.64	4.23±0.68	0.604 (P<.001)
	Exp.	4.23±0.63	4.20±0.71	
	P	.839	.854	

BMI=body mass index, Con.=control subgroup, Exp.=experimental subgroup.

Table 5**Display of lesions in the images for the 2 subgroups, the control group and the experimental group, in the 4 groups.**

Group		Normal	Ground -glass	Nodules	Fibrous stripes	Calcification	Bullous emphysema	χ^2	P-value
Group 1:	Con.	72	3	32	45	18	9	1.434	.921
	Exp.	75	2	28	37	15	11		
Group 2:	Con.	62	5	12	26	16	7	3.552	.616
	Exp.	53	7	15	28	13	13		
Group 3:	Con.	47	2	6	13	12	5	4.057	.541
	Exp.	42	0	9	17	13	8		
Group 4:	Con.	18	0	5	11	8	4	1.504	.913
	Exp.	20	1	5	9	7	3		

Con. = control subgroup, Exp. = experimental subgroup.

patient's mammary gland during the examination. In summary, the XCARE technology in female chest CT screening can obtain the same image quality and radiation dose compared to conventional chest CT scans, which can be used regularly in female patients.

Author contributions

Conceptualization: Cheng Li.

Data curation: Cheng Li.

Investigation: Yusheng Zhang, Lukai Zhang.

Methodology: Lin Qi.

Resources: Feng Gao.

Software: Feng Gao, Lukai Zhang.

Supervision: Xiu Jin.

Validation: Xiu Jin.

Visualization: Huan Tang.

Writing – original draft: Cheng Li, Ming Li.

Writing – review & editing: Cheng Li, Lin Qi.

References

- Blanchon T, Brechot JM, Grenier PA, et al. Baseline results of the Depiscan study: a French randomized pilot trial of lung cancer screening comparing low dose CT scan (LDCT) and chest X-ray (CXR). *Lung Cancer (Amsterdam, Netherlands)* 2007;58:50–8.
- Borondy Kitts AK. The patient perspective on lung cancer screening and health disparities. *J Am Coll Radiol* 2019;16:601–6.
- Hardy AJ, Bostani M, McMillan K, et al. Estimating lung, breast, and effective dose from low-dose lung cancer screening CT exams with tube current modulation across a range of patient sizes. *Med Physics* 2018;45:4667–82.
- Biermann J, Langen B, Nemes S, et al. Radiation-induced genomic instability in breast carcinomas of the Swedish hemangioma cohort. *Genes Chromosomes Cancer* 2019;58:627–35.
- Ketelsen D, Buchgeister M, Fenchel M, et al. Automated computed tomography dose-saving algorithm to protect radiosensitive tissues: estimation of radiation exposure and image quality considerations. *Invest Radiol* 2012;47:148–52.
- Yang WJ, Yan FH, Liu B, et al. Can sinogram-affirmed iterative (SAFIRE) reconstruction improve imaging quality on low-dose lung CT screening compared with traditional filtered back projection (FBP) reconstruction? *J Comput Assist Tomogr* 2013;37:301–5.
- Tang H, Yu N, Jia Y, et al. Assessment of noise reduction potential and image quality improvement of a new generation adaptive statistical iterative reconstruction (ASIR-V) in chest CT. *Br J Radiol* 2018;91:20170521.
- Hidajat N, Maurer J, Schroder RJ, et al. Relationships between physical dose quantities and patient dose in CT. *Br J Radiol* 1999;72:556–61.
- Liu W, Ding X, Kong B, et al. Reducing the radiation dose with the adaptive statistical iterative reconstruction technique for chest CT in adults: a parameter study. *Chin Med J* 2014;127:1284–8.
- Deak PD, Smal Y, Kalender WA. Multisection CT protocols: sex- and age-specific conversion factors used to determine effective dose from dose-length product. *Radiology* 2010;257:158–66.
- Barcellos-Hoff MH. New biological insights on the link between radiation exposure and breast cancer risk. *J Mammary Gland Biol Neoplasia* 2013;18:3–13.
- Martin K, Vogel RI, Nagler RH, et al. Mammography Screening Practices in Average-Risk Women Aged 40–49 Years in Primary Care: A Comparison of Physician and Nonphysician Providers in Minnesota. *J Womens Health (Larchmt)* 2020;29:91–9.
- Kidoh M, Utsunomiya D, Oda S, et al. Breast dose reduction for chest CT by modifying the scanning parameters based on the pre-scan size-specific dose estimate (SSDE). *Eur Radiol* 2017;27:2267–74.
- Franck C, Smeets P, Lapeire L, et al. Estimating the patient-specific dose to the thyroid and breasts and overall risk in chest CT when using organ-based tube current modulation. *Radiology* 2018;288:164–9.
- Vollmar SV, Kalender WA. Reduction of dose to the female breast in thoracic CT: a comparison of standard-protocol, bismuth-shielded, partial and tube-current-modulated CT examinations. *Eur Radiol* 2008;18:1674–82.
- Fu W, Tian X, Sturgeon GM, et al. CT breast dose reduction with the use of breast positioning and organ-based tube current modulation. *Med Physics* 2017;44:665–78.
- Spampinato S, Gueli AM, Milone P, et al. Dosimetric changes with computed tomography automatic tube-current modulation techniques. *Radiol Physics Technol* 2018;11:184–91.
- Muller K, Meineke V. Advances in the management of localized radiation injuries. *Health Physics* 2010;98:843–50.
- Wang J, Duan X, Christner JA, et al. Radiation dose reduction to the breast in thoracic CT: comparison of bismuth shielding, organ-based tube current modulation, and use of a globally decreased tube current. *Med Physics* 2011;38:6084–92.
- Lungren MP, Yoshizumi TT, Brady SM, et al. Radiation dose estimations to the thorax using organ-based dose modulation. *AJR Am J Roentgenol* 2012;199:W65–73.