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Original Article

Application effect of low-dose spiral CT on pulmonary nodules and its diagnostic value for benign and malignant nodules

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Abstract: Objective: This study was designed to determine the application effect of low-dose computed tomography (LDCT) on detecting pulmonary nodules (PNs) and its diagnostic value for benign and malignant pulmonary nodules. Methods: Data of 432 patients with PNs admitted to Julu County Hospital between March 2018 and June 2021 in were collected and analysed retrospectively. All patients underwent LDCT and conventional-dose spiral computed tomography (CT). The detection rate and image characteristics of the two methods were compared, and the image quality and radiation dose of the two diagnostic methods were also compared. Results: No significant difference was found between LDCT and conventional-dose spiral CT in the detection rate of lung cancer (P>0.05). The area under the curve of conventional-dose CT was 0.932, with a specificity and sensitivity of 93.87% and 92.45%, and the area under the curve of LDCT was 0.902, with a specificity and sensitivity of 90.80% and 89.62%. The radiation dose consumed during LDCT was greatly less than that consumed by conventional-dose CT (P<0.05). Additionally, the two methods were not different in CT image quality and superior vena cava artifact (P>0.05). No notable difference was found between LDCT and conventional-dose CT in terms of the diagnosis rate of PNs in vascular aggregation sign, pleural indentation sign, lobulation sign and spiculation sign. Conclusion: LDCT can clearly show the typical images of early lung cancer, with less effective radiation dose, and can thus contribute to a high detection rate, so it is worth popularizing.

Keywords: Low-dose spiral CT, pulmonary nodules, benign and malignant nodules, diagnostic value

Introduction

The morbidity and mortality of lung cancer (LC) both rank the first among malignant tumours [1]. Its overall 5-year survival rate is only about 10%. The 5-year survival rate of patients with middle or advanced LC who can receive whole resection is 20-40%, while that of patients with advanced LC who cannot receive it is only 2-3% [2, 3]. However, the 5-year survival rate of patients with early LC after surgical resection is 70-100%. Thus, early detection, early diagnosis and early treatment are the key to improving the survival rate of LC patients [4]. Early LC usually has small nodules in the lungs, which are considered as the key features for judging primary LC [5]. However, not all lung nodules are malignant lesions, so the identification and prediction of lung nodules are importance steps for early diagnosis of LC [6].

X-ray chest films are mostly adopted in clinical diagnosis of pulmonary nodules (PNs), and more than 90% of patients with PNs have obvious abnormal chest films. However, the accuracy of X-ray chest films is limited for patients with early LC, and its diagnostic value is also limited by the existence of "blind areas" and unfavourable density resolution [7]. Spiral CT scanning is extensively adopted in clinic for the diagnosis of many diseases because of its stereoscopic, intuitive and continuous scanning characteristics. However, in terms of the high radiation dose of CT examination, there are always doubts about its application value in lung diseases [8].

In recent years, low-dose computed tomography (LDCT) for LC has become a hot spot. In terms of the detection rate, some studies have pointed out that compared with that of chest

X-ray, the detection rate of LDCT is 3 times higher for PNs, 4 times higher for LC, and 6 times higher for stage I LC [9]. In terms of lowering the total mortality, the results of 33 research sites in the United States showed that the number of deaths from LC in the LDCT group was 6.7% lower than that in the X-ray group, and the death rate due to LC decreased by about 20% [10]. Therefore, in 2013, the American Cancer Society recommended LDCT for people at a high risk of LC and developed relevant screening guidelines [11]. In addition, currently, LDCT screening can assist in the diagnosis of other diseases, such as emphysema and coronary artery calcification, providing additional benefits for screening subjects [12]. At present, more experts recommend LDCT screening for eligible high-risk groups, but some experts express concern about the high false positivity and radiation [13]. Meta analysis by Brodersen et al. [14] showed that 49% of the tumours found in large-scale LDCT screening for lung cancer were misdiagnosed. Additionally, prior research has revealed that for the sake of safety, LDCT uses less radiation dose, so the images have problems such as poor contrast, noise and fringe artifacts, which compromises the diagnostic performance [15].

In order to determine the effect of LDCT in the examination of pulmonary nodules, this study explored the value of LDCT in the diagnosis of benign and malignant pulmonary nodules and the radiation dose consumed by LDCT, and also analysed the efficiency of LDCT in the diagnosis of morphological characteristics of pulmonary nodules.

Methods and data

Patient data

In this retrospective study, data of 432 patients with PNs treated in Julu County Hospital between March 2018 and June 2021 were retrospectively analysed, including 279 males and 153 females, with a mean age of 60.5±8.2 years. According to the pathological results (needle biopsy guided by CT or ultrasound), 326 patients with benign nodules and 106 patients with malignant nodules were assigned to different groups. All patients underwent LDCT and conventional-dose spiral CT scanning. This study was conducted with approval from the medical ethics committee (approval number: 2021-10).

Inclusion and exclusion criteria

Inclusive criteria: Patients with confirmed PNs by pathological biopsy; patients who had not received treatment for PNs; patients who volunteered to participate in the research; patients with detailed clinical case data; patients with normal cognition ability.

Exclusion criteria: Patients with more than one lung nodule or mass shadow in the lung; patients with bronchiectasis, inflammation, severe emphysema or other pathological changes in the lung; patients with intolerance to this inspection; patients with major organ diseases; patients with abnormal coagulation mechanism.

Detection methods

Before scanning, each patient was instructed to do breathing training to practice holding breath, and then received multi-slice spiral CT (PHILIPS, 64 rows), with the scanning range from the top of the lung to the top of the diaphragm. (1) For conventional-dose spiral CT scanning, the parameters were as follows: tube current: 150 mAs; tube voltage: 140 kV; layer spacing: 5 mm; layer thickness: 5 mm; pitch: 1.0 mm; reconstruction matrix: 512 × 512. (2) For LDCT scanning, the parameters were as follows: tube current: 50 mAs; tube voltage: 140 kV; layer spacing: 5 mm; layer thickness: 5 mm; pitch: 1.0 mm; reconstruction matrix: 512 × 512. All the original images were processed and analysed by workstation.

Image evaluation criteria

After image processing, two experienced radiologists evaluated the films separately with a double-blind method. The main contents of film reading included the size, number, indirect signs, lesion morphology, noise level and artifacts, etc. The image quality was scaled as five grades: 1 point: unqualified image that could not meet the diagnostic requirements; 2 points: poor image quality that could not meet the diagnostic requirements; 3 points: general image quality that can be used for diagnosis; 4 points: good image quality; 5 points: high image quality. If there was a difference in opinion between the two radiologists, another expert was invited for consultation, and a final unified opinion was reached through discussion.

Outcome measures

(1) With the final pathological results of patients as the gold standard, the diagnostic results of benign and malignant PNs by two imaging methods were assessed, and the specificity, sensitivity and accuracy of the two imaging methods were compared to evaluate their diagnostic efficiency. (2) The image quality from the two imaging methods was evaluated, and the proportions of image quality score ≥3 points were compared. (3) The radiation dose consumed by the two imaging methods was measured through volume CT dose index (CTDIvol) and dose length product (DLP) automatically recorded by CT. (4) The difference in the detection rate of pulmonary nodule signs between the two imaging methods was compared. The pulmonary nodule signs included vascular aggregation sign, pleural indentation sign, lobulation sign and spiculation sign.

Statistical analyses

This study adopted SPSS 20.0 (SPSS Inc., Chicago, IL, USA) for statistical analysis of all data. The Chi-square test was adopted for comparing the rates, and the results were expressed as X^2. All the measurement data were in normal distribution, and they were analysed using the independent-sample t test, and presented as t. Receiver operating characteristic curves were drawn to compare the diagnostic efficiency of the two methods. GraphPad Prism 7 (GraphPad Software, Inc., San Diego, CA, USA) was adopted for plotting figures. $P<0.05$ suggests a significant difference.

Results

Baseline data of patients

The baseline data of participants are summarized in **Table 1**. Between the two groups there was no statistical difference in terms of sex, age, diameter of nodules, nodular site and nodule type ($P>0.05$), but there were significant differences in nodule size change, history of smoking, history of pulmonary infection and family history of cancer ($P<0.05$).

Analysis on diagnostic results of the two methods

With the gold standard, 106 cases of LC positive were diagnosed. With conventional-dose CT, 98 cases of LC positive were diagnosed, and with LDCT, 95 cases of LC positive were diagnosed. The specificity and sensitivity of conventional-dose CT were 93.87% and 92.45%, respectively, and the specificity and sensitivity of LDCT were 90.80% and 89.62%, respectively (**Table 2**).

Comparison of diagnostic efficiency between the two methods

The specificity, sensitivity and accuracy of LDCT were all slightly lower than those of conventional-dose CT, and the area under the curve of conventional-dose CT was 0.932 and that of LDCT was 0.902 ($P>0.05$, **Table 3**; **Figure 1**).

Comparison of radiation dose consumed by the two methods

We counted the CTDIvol and DLP, and found significantly lower CTDIvol and DLP consumed by LDCT than those by conventional-dose CT ($P<0.05$, **Figure 2**).

Comparison of image quality between the two methods

For conventional-dose CT the image quality score of ≥3 points accounted for 96.30%, and that of LDCT accounted for 94.44%, but the difference between the two was not significant (**Table 4**).

Diagnosis results of morphological characteristics of PNs

According to comparison in the diagnostic results of morphological features of PNs, the two methods were not greatly different in the diagnosis of four features: vascular aggregation sign, pleural indentation sign, lobulation sign and spiculation sign (**Table 5**).

Discussion

Because of the small tissue damage and lesions of PNs, patients rarely have corresponding clinical symptoms, and only occasionally have cough, fever, fatigue, loss of appetite, night-sweat and other symptoms, so PNs are

Table 1. Baseline data

	Benign nodules (n=326)	Malignant nodules (n=106)	χ^2/t	P
Sex			0.686	0.408
Male	207 (63.50)	72 (67.92)		
Female	119 (36.50)	34 (32.08)		
Age (years)	60.28±8.31	61.08±7.82	0.873	0.383
Diameter of nodules (mm)	18.30±2.60	18.80±2.31	1.766	0.078
Nodular site			0.241	0.624
Left	151 (46.32)	52 (49.06)		
Right	175 (53.68)	54 (50.94)		
Nodule type			3.066	0.216
Subsolid	111 (34.05)	35 (33.02)		
Solid	191 (58.59)	68 (64.15)		
Pure ground glass	24 (7.36)	3 (2.83)		
Nodule size change			13.060	0.001
No	284 (87.12)	77 (72.64)		
Enlarged	25 (7.67)	20 (18.87)		
Unclear	17 (5.21)	9 (8.49)		
History of smoking			3.940	0.047
Yes	47 (14.42)	24 (22.64)		
No	279 (85.58)	82 (77.36)		
History of pulmonary infection			3.204	0.001
Yes	34 (10.43)	24 (22.64)		
No	292 (89.57)	82 (77.36)		
Family history of cancer			8.117	0.004
Yes	11 (3.37)	11 (10.38)		
No	315 (96.63)	95 (89.62)		

Table 2. Diagnosis results

Diagnostic mode		Gold standard		Total
		Positive	Negative	
Conventional-dose CT	Positive	98	20	118
	Negative	8	306	314
	Total	106	326	
LDCT	Positive	95	30	109
	Negative	11	296	307
	Total	106	326	

LDCT: Low-Dose Computed Tomography.

Table 3. Comparison of diagnostic efficiency between the two imaging methods

	Specificity	Sensitivity	Accuracy
Conventional-dose CT	93.87%	92.45%	93.52%
LDCT	90.80%	89.62%	90.51%
χ^2	2.166	0.520	2.662
P	0.141	0.471	0.103

CT: Computed Tomography; LDCT: Low-Dose Computed Tomography.

often accidentally found in physical examination or during the diagnosis and treatment of other diseases [16]. From a conceptual point of view, pulmonary nodule belongs to a kind of imaging manifestation, and benign pulmonary inflammation and enlarged lymph nodes can present as PNs, which can easily evolve into LC as the disease develops, and increase the mortality, so early screening and diagnosis are imperative [17]. With advantages of high spatial resolution, clear imaging and simple operation, spiral CT can scan the whole chest in a short time to prevent the image artifacts caused by respiratory movement. The post-processing of three-dimensional reconstruction technology can directly display the edge, density, size, location, shape and relationship of the surrounding tissues of the lesions. Therefore, spiral CT is a common method to diagnose the morphological characteristics of PNs.

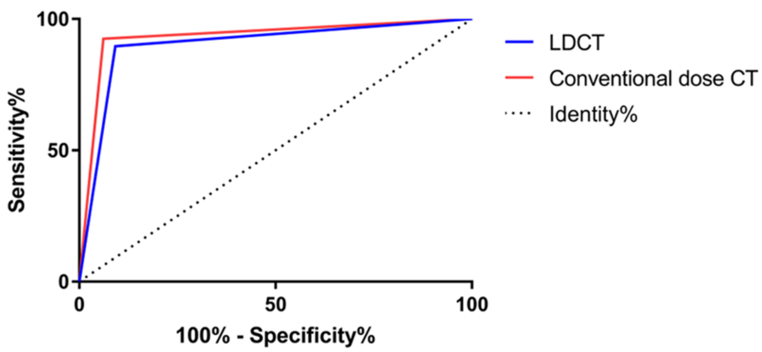

Figure 1. Receiver operating characteristic curve of two diagnostic methods. The area under the curve of conventional-dose CT was 0.932 and that of LDCT was 0.902. CT: Computed Tomography; LDCT: Low-Dose Computed Tomography.

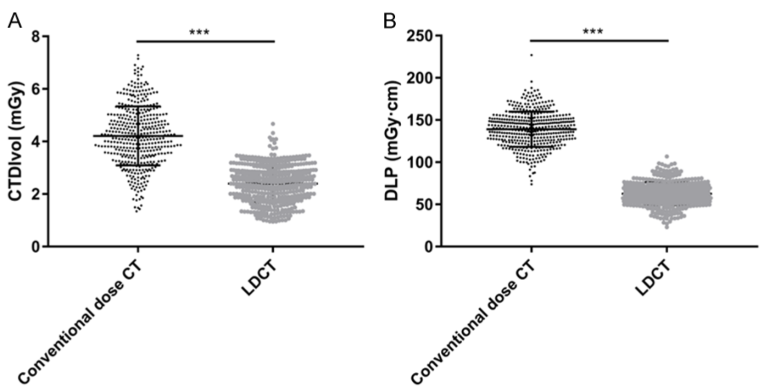

Figure 2. Radiation dose of the two detection methods. A, B: The CTDIvol and DLP of LDCT were greatly lower than those of conventional-dose CT. ***P<0.001. CTDIvol: CT Dose Index; DLP: Dose Length Product; CT: Computed Tomography; LDCT: Low-Dose Computed Tomography.

Table 4. Image quality

	Conventional-dose CT (n=432)	LDCT (n=432)	X^2	P
Image quality score				
5 points	160 (37.04)	107 (24.77)		
4 points	184 (42.59)	192 (44.44)		
3 points	72 (16.67)	109 (25.23)		
2 points	14 (3.24)	18 (4.17)		
1 points	2 (0.46)	6 (1.39)		
≥3 points	416 (96.30)	408 (94.44)	1.678	0.195

CT: Computed Tomography; LDCT: Low-Dose Computed Tomography.

According to the comparisons of the diagnostic results and diagnostic efficacy between conventional-dose spiral CT and LDCT in benign and malignant nodules in this study, the two methods were similar in specificity, sensitivity and accuracy. Two experienced radiologists were arranged to evaluate the image quality. The results showed no notable difference between the two diagnostic methods in subjectively evaluated image quality score. Wei et al. [18] combined SHOX2, RASSF1A and PTGER4 methylation biomarkers to improve the diagnostic efficiency to solve the false positive of LDCT in the diagnosis of LC. Additionally, in order to reduce the increasing workload of radiologists, artificial intelligence system has been introduced into imaging. The introduction of this auxiliary coordination has improved the accuracy of diagnosis [19]. Prior research has revealed that compared with the traditional two-doctor evaluation, the application of the computer-aided testing system as the second reader for the detection of pulmonary nodules has greatly improved the average sensitivity from 63% (range 56-67%) to 76% (range 73-78%) [20].

Chemical ionization is the physiological basis of radiation damage to human body, and the ions produced during ionization are directly correlated with the damage. Hydroxyl radicals produced by water molecules under ionization can lead to DNA strand breakage and base destruction, and even directly cause DNA damage [21, 22]. In addition, the body injury caused by radiation can easily increase the risk of cancerization, but reduction of radiation dose along may increase the difficulty in acquiring high-quality scanning images, so the clinical value of spiral CT in the diagnosis of lung diseases is still doubtful. In this study, no significant difference was found between LDCT and

Table 5. Diagnosis results of morphological characteristics of PNs

	Conventional-dose CT (n=432)	LDCT (n=432)	χ^2	P
Vascular aggregation sign	89 (20.60)	84 (19.44)	0.181	0.671
Pleural indentation	101 (23.38)	95 (21.99)	0.238	0.626
Lobulation sign	160 (37.04)	145 (33.56)	1.140	0.286
Spiculation sign	129 (29.86)	109 (25.23)	2.320	0.128

CT: Computed Tomography; LDCT: Low-Dose Computed Tomography.

conventional-dose spiral CT in the specificity, sensitivity, accuracy of positive predictive value and negative predictive value of PNs, and the detection rate of PNs. The present study confirmed that the diagnostic value of conventional-dose CT and LDCT for PNs was basically the same. According to further comparison of the CT radiological indexes between the two examination methods, the CTDIvol and DLP of LDCT were lower than those of conventional-dose CT. The results indicate that LDCT causes less radiation damage while ensuring high diagnostic value, so it is more conducive to protecting the safety of patients. Because the lungs are rich in gas in contrast to other high-density soft tissues such as skeletal muscle, the reduction of tube current and tube voltage can achieve the purpose of reducing the dose of ionizing radiation received by patients as much as possible, and the radiation damage to the human body can be thus notably reduced [23]. LDCT can clearly display the lobar bronchus of the patients, including mixed nodules and tiny solid nodules less than 5 mm. After reconstruction with three-dimensional post-processing technology, the shape of the lesions can be displayed more comprehensively, which is convenient for doctors to observe the relationship between the lesion and surrounding tissue. Crosbie et al. [24] also mentioned that LDCT could reduce the mortality of LC, and telephone-based risk assessment and community-level lung health examination are also effective strategies to implement LC screening. However, smoking status and socio-economic poverty can make the participation rate low, which is also an obstacle for screening.

This study has some limitations. First, the results of imaging examination could be impacted by the skill of operating technicians, so the possibility of missed diagnosis and misdiagnosis cannot be completely ruled out. Second, the existence of artifacts can also not be completely avoided for the influence of patients' breath holding and breathing [25]. Third, during the practical application of LDCT to detect symptoms, it is necessary to ensure the high quality of the scanning image standard. According to the long-term case study, the low-dose interval standard of 25-75 mA is optimal [26, 27]. If the tube current is reduced to 20 mAs, it will cause artifacts at the tip of the lung, which can directly disrupt the diagnosis of the disease. However, LDCT inspection can reduce the loss of CT tubes and detectors, helping prolong the service life of inspection equipment and further reducing the operating costs of CT.

To sum up, LDCT can clearly show the typical images of early LC, with less effective radiation dose, and can thus contribute to a high detection rate, so it is worth popularizing.

Disclosure of conflict of interest

None.

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