Effects of CT images with different reconstruction energy on radiotherapy planning for patients with non-small cell lung cancer

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Abstract

BACKGROUND

With the development of the CT technology, multi-energy technology is applied to CT imaging, which improves the time resolution, spatial resolution and density resolution of CT system. It enables the CT imaging system to achieve clearer image display under safe and low-dose conditions, so that the disease can be displayed more quickly, and the disease can be identified more early and more clearly.

METHODS

38 non-small cell lung cancer patients were selected for energy spectral scanning. All energy spectral images obtained were transferred to the Discover™ CT post-processing workstation to generate 40 keV, 60 keV, 80 keV, 100 keV, 120 keV, and 140 keV single-energy images. Then the single-energy images were imported to Eclipse, and the oncologist contours the target area and organs at risk (OARs) on the single-energy images described above, and then the physicist designed radiotherapy plans to perform statistical analysis on the tissue CT value and target volume of each single-energy image, and to compare dosimetry of different plans about the organs at risk and the target area.

RESULTS

The CT values of GTV, heart, lung, and spinal cord of different energy CT images are statistically different ($P < 0.05$). Among them, the CT value of each tissue obtained in the 40 keV group is the largest, and the CT value decreases with the increase of energy. There were no statistically significant differences in the homogeneity index(HI), the conformity index(CI), the maximum dose, the minimum dose and the average dose of the gross tumor volume (GTV) delineated on CT images of different energy ($P > 0.05$), as well as the organs at risk.

CONCLUSIONS

When CT images of different energies obtained from energy spectral CT scans are used in the design of radiotherapy planning, there are no significant differences in target area outlines and doses caused by energy factors, but the differences in tissue CT values have statistical significant.

1 Background

With the development of CT technology, spectral CT has been widely used in recent years, which include in the security check, calculi ingredient analysis, diagnosis of gout and bone marrow edema, and the early diagnosis of tumors, etc[1–7]. Compared with traditional CT, spectral CT has a variety of advantages, including the ability to generate energy decay curves, iodine-based maps, water-based maps, and virtual

plain scans, which lays a broad application prospect for qualitative diagnosis and quantitative analysis of lesions. At present, the application of spectral CT is mainly used in chest and abdomen examinations. The advantage of virtual plain scan can not only reduce the patient's exposure dose, and reduce the error caused by the inconsistency of the measurement of the area of interest before and after the scan, but also conduct a differential analysis of the nature of the lesion [8–9]. Energy spectrum CT uses a single X-ray tube, spectral imaging through single-source instant kV switching technology, and determines the attenuation coefficient of the voxel in the energy range of 40–140 keV based on these two energy data, and further obtains 101 single-energy images. This relatively pure single-energy image can greatly reduce the impact of hardening artifacts and obtain a relatively pure CT value image, that is, the CT value is more consistent and reliable regardless of the position, scan in the entire visual field, or patient [10]. In the image processing, different substances are decomposed into matrix pairs based on photoelectric effect, and the electron density, effective atomic number, and matrix distribution density are calculated to provide more diagnostic information for the clinic, which expanded the diagnostic application of CT [11]. The development of spectral CT technology also poses new challenges to radiotherapy simulation positioning technology, that is, how to apply spectral CT technology to improve the accuracy of CT value-tissue parameter conversion, thereby improving the accuracy of radiotherapy.

Before radiotherapy, the patient needs to perform a positioning scan on a CT simulator to obtain CT images containing the patient's anatomy and position information and then imported into the radiotherapy planning system. The treatment planning system obtains the conversion curve of CT value and relative electron density of the tissue from the CT images, and, the inhomogeneous tissue needs to be calibrated based on the relative electron density of the tissue, and then the dose calculation is performed [12–14]. In order to obtain clear CT images, the patient's scanning conditions will be different during simulated positioning scans, such as scan voltage, scan current, or scan layer thickness. These will affect the CT value and the relative electron density conversion curve, which will affect the patient's dose calculation of the radiotherapy plan. This study used single-energy images obtained by spectral CT to study the effects of CT images of different energies on the radiotherapy plan for patients with non-small cell lung cancer, to guide the setting of scanning conditions during radiotherapy simulation positioning, and to reduce the influencing factors of dose calculation in radiotherapy plan in order to improve the accuracy of radiotherapy.

2 Methods

2.1 Case presentation

Eight patients with lung non-small cell lung cancer confirmed by pathological biopsy were selected, including 23 cases with lesions on the left and 15 cases on the right lung. The male to female ratio was 21:17. The age range of the selected patients is 55–75 years, with an average age of 61.2 years.

2.2 Equipment and software

All inspections use the gemstone (Discover™ CT 750HD, GE Healthcare, USA) energy spectrum scanning mode. The planning system is the Eclipse 10 radiotherapy planning system.

2.3 Positioning and scanning

The patients took a supine position with the head advanced, and the scanning range was from the thorax entrance to the diaphragm level, including the energy spectrum scan of the entire lung. Scanning conditions: The tube voltage is instantaneously switched from 40 kVp to 140 kVp, the tube current is 550 mA, the rotation time is 0.8S, the layer thickness is 5 mm, while the spacing is 5 mm, the reconstruction interval is 1.25 mm, and the pitch is 1.375 mm.

2.4 Post-processing of CT images

Transfer all energy spectrum imaging data to the post-processing workstation (AW4.5), and reconstruct to generate single-energy images of 40 keV, 60 keV, 80 keV, 100 keV, 120 keV, 140 keV, then transfer the single-energy images to the Eclipse 10 treatment planning system .

2.5 Contouring of target areas and OARs

According to the ICRU83 report and the RTOG1106 consensus, senior clinical physicians contoured the target areas and organs at risk on the single-energy CT images described above [15]. GTV includes the primary tumor and metastatic lymph nodes in the mediastinum and supraclavicular region determined by the images. The clinical target volume(CTV) is 3 mm of the upper and lower ends of GTV, 5 mm of axial extension. Then generate PTV by expansion of 8 mm in all directions from the CTV. The OARs, such as the lungs, spinal cord, and heart were contoured respectively.

2.6 Planning techniques

The plans were generated using the Eclipse10 (Varian Inc) treatment planning system. All of the treatment plans were delivered using a 6-MV photon beam. 7-Field intensity modulated radiation therapy(IMRT) plans were completed by senior physicists, and physicians with deputy directors or above have reviewed and evaluated the uniformity of target dose and organ-endangered doses through some dosimetry-related indicators. All patients had a PTV dose of 60 Gy / 30 fractions and the treatment planning objectives were to cover 95% of the planning target volume a maximum dose of 120%. The plans of all different energy CT images of the same patient uses the same field energy, field direction, optimization parameters, and dose calculation algorithm (AAA). On a single-energy image, a plan that meets the prescription requirements and endangers the organ limit is used. And based on this plan template, the plans of other energy groups were designed separately. For the OARs, the planning objectives were maximal doses of 45 Gy for the spinal cord. $V_{40} < 30\%$, $V_{30} < 40\%$, $D_{\text{mean}} < 25\text{Gy}$, for the heart. $V_5 < 60\%$, $V_{20} < 30\%$ and $V_{30} < 20\%$ for both lungs. These planning objectives for the OARs were uniform for all patients and were established following the strictest constraint recommendations to assure the lowest possible dose delivered to normal tissues.

2.7 Evaluation parameters

The target area HI refers to ICRU83 report and defines as follows:

$$HI = (D_{2\%} - D_{98\%}) / D_{50\%} \quad (1)$$

In which, $D_{2\%}$ represents the irradiation dose received by 2% of the target volume, $D_{98\%}$ represents the irradiation dose received by 98% of the target volume, and $D_{50\%}$ represents the irradiation dose received by 50% of the target volume.

And the CI is:

$$CI = (V_{t,ref} / V_t) \times (V_{t,ref} / V_{ref}) \quad (2)$$

Where V_t is the volume of the target area, $V_{t,ref}$ is the volume of the target area surrounded by the reference isodose line surface, and V_{ref} is the volume of all areas surrounded by the reference isodose line. The closer the CI value is to 1, the better the conformal coverage is.

Compare the CT value of tissues and GTV volume with different energy CT images. Evaluate HI, CI, maximum dose D_{max} , minimum dose D_{min} , and average dose D_{mean} in the target area. For the OARs, the planning objectives were maximal doses of 45 Gy for the spinal cord. Evaluate V_{40} , V_{30} , and D_{mean} for the heart, and V_5 , V_{20} and V_{30} for both lungs.

2.8 Statistical methods

The data were divided into 6 groups based on different energies, which are 40 keV group, 60 keV group, 80 keV group, 100 keV group, 120 keV group, and 140 keV group. SPSS 20.0 software was used to analyze the measurement data. All measurement data were firstly tested for normality. When the measurement data obey the normal distribution and the variance is homogeneous, one-way analysis of variance (ANOVA) is performed. Otherwise, when the variance is not uniform, Brown-Forsythe and Welch tests are used. $P < 0.05$ is considered statistically significant.

3 Results

The study subjects were images of 6 groups of different energies from 38 patients with non-small cell lung carcinoma. For the 228 plans obtained, CT values of tissues, target volume, target dose and organ-endangered dose were included as comparative indicators for analysis. All measurement data conform to the normal distribution. The results are expressed as the mean plus or minus standard deviation ($\bar{x} \pm SD$), with two significant digits after the decimal point and three significant digits after the decimal point for the mean of HI and CI.

3.1 Comparison of CT values of different energy CT images

After transmitting the CT images to the planning system, the physician contoured the GTV, CTV, PTV and OAR(the left lung, right lung, heart, and spinal cord). Then, 5 points are randomly selected within each

contoured structure, and the CT value of the corresponding points is read by the planning system, and the arithmetic average of the CT values of these 5 points is used as the CT value of the tissue. In this study, the CT values GTV, heart, lung, and spinal cord were selected for univariate analysis of variance. The results are shown in Table 1:

Table 1
CT values obtained from different energy groups

Group	GTV	Heart	Lung	Spinal Cord
40 keV	147.97 ± 69.98	318.63 ± 54.28	-782.42 ± 65.17	73.88 ± 27.81
60 keV	78.38 ± 33.11	159.95 ± 23.06	-818.26 ± 57.80	45.18 ± 13.60
80 keV	52.98 ± 17.88	97.29 ± 12.55	-831.63 ± 55.08	30.29 ± 8.23
100 keV	39.82 ± 12.59	67.66 ± 12.23	-838.08 ± 54.12	24.54 ± 6.60
120 keV	35.01 ± 9.31	56.54 ± 8.04	-840.44 ± 53.30	22.38 ± 5.50
140 keV	31.67 ± 7.95	48.86 ± 7.79	-842.19 ± 53.19	20.78 ± 5.20
<i>F value</i>	N/A	N/A	N/A	N/A
<i>P value</i>	N/A	N/A	N/A	N/A
<i>Brown-Forsythe*</i>	0.000	0.000	0.000	0.000
<i>Welch*</i>	0.000	0.000	0.000	0.000
Note: N/A illustrates that the variance is not uniform, this value is not applicable; Brown-Forsythe * is the significant result of Brown-Forsythe test, Welch * is the significant result of Welch test, and when the significant result is less than 0.05, the difference is statistically significant.				

As can be seen from the table above, the P values for the CT values of the four tissues are all less than 0.05, and the differences in CT values of the same patient at different energy levels are statistically significant. Figure 1 shows the graphs of CT values for different tissues under different energies, which indicated that the CT values of the four tissues decreased with increasing energy. The range of CT values of the heart and lung varies widely, while that of the spinal cord is small.

3.2 Comparison of differences in GTV contouring

On the planning system, the volume of the GTV contoured by the physician was obtained. The results are shown in Table 2. Which shows that the P value was greater than 0.05, so the difference was not statistically significant.

Table 2
The volume of the GTV for different energies

Group	n	GTV Volume
40 keV	8	105.38 ± 140.98
60 keV	8	102.51 ± 132.75
80 keV	8	102.65 ± 135.83
100 keV	8	100.91 ± 132.12
120 keV	8	100.17 ± 131.66
140 keV	8	101.64 ± 135.99
<i>F value</i>		0.001
<i>P value</i>		1.000

Six pairs of data above are compared pairwise. Among them, the 40 keV energy group has the largest GTV volume, reaching $105.38 \pm 140.98 \text{ cm}^3$, and the 120 keV energy group has the smallest average volume. $(V_{\max} - V_{\min}) / V_{\max} \times 100\%$ was used to indicate the difference between the maximum and the minimum, and the value for GTV is 4.94%. The smallest difference for GTV volume is between 60 keV and 80 keV, which is only 0.14%.

The CT images of different energies have different display details, as shown in Fig. 2.

3.3 Dosimetric comparison of planning target areas

All plans take PTV as the target area, and the PTV information including $D_{\max}$, D_{mean} , $D_{\min}$, $D_{2\%}$, $D_{98\%}$, $D_{50\%}$, $V_{\text{PTV}100\%}$, V_{PTV} , and V_t of all 228 plans were obtained in order to get the CI and HI. And one-way analysis of variance was performed. The data are shown in Table 3.

From Table 3 we can see that, the maximum HI value is 0.166, while the minimum value is 0.131. When compared between groups, $P > 0.05$, so the difference is not statistically significant. The maximum value of CI is 0.721, when the minimum value is 0.686. Considering the comparison between groups, $P > 0.05$, obviously, the difference is not statistically significant. In summary, when planned with different energies, the uniformity and conformity of the target area are not affected by the energy.

Table 3
Target dose analysis

Groups	HI	CI	D _{max}	D _{mean}	D _{min}
40 keV	0.131 ± 0.02	0.719 ± 0.06	6775.31 ± 100.36	6272.15 ± 45.29	5050.05 ± 681.04
60 keV	0.142 ± 0.02	0.709 ± 0.06	6798.03 ± 165.11	6301.31 ± 63.79	5033.33 ± 655.13
80 keV	0.166 ± 0.05	0.721 ± 0.06	6917.22 ± 302.17	6364.31 ± 111.46	4940.53 ± 684.68
100 keV	0.154 ± 0.03	0.686 ± 0.07	6858.11 ± 209.30	6335.30 ± 72.32	5104.70 ± 430.31
120 keV	0.162 ± 0.02	0.704 ± 0.08	6929.90 ± 159.26	6367.44 ± 80.49	5124.29 ± 391.38
140 keV	0.157 ± 0.02	0.687 ± 0.07	6864.74 ± 195.86	6345.21 ± 72.15	4988.88 ± 654.46
<i>Fvalue</i>	1.879	0.400	0.780	1.896	0.108
<i>Pvalue</i>	0.119	0.846	0.570	0.115	0.990

When compared between groups, it can be shown from the table above that the P value was greater than 0.05, and the maximum group of D_{max}, D_{mean}, and D_{min} were all 120 keV group, which were 6929.90 ± 159.26, 6367.44 ± 80.49, and 5124.29 ± 391.38 respectively. Both D_{max} and D_{mean} minimum values appeared in the 40 keV group, values 6775.31 ± 100.36 and 6272.15 ± 45.29, which meeting the requirements of the plan. The maximum and minimum values of D_{max} differ by 4.49%, D_{mean} by 1.49%, and D_{min} by 3.58%, all within 5%.

3.4 Dosimetric comparison of lung tissue, heart, and spinal cord

(1) Lung dose comparison

The lungs were divided into affected lungs and healthy lungs for dose comparison. For both lungs, V₅, V₂₀, V₃₀ and D_{mean} were evaluated respectively.

The lung is divided into the ipsilateral lung and the healthy lung for dose comparison, and the V₅, V₂₀, V₃₀ and D_{mean} are evaluated. The results are shown in Tables 4 and 5.

Table 4
Dose of the ipsilateral lung

Groups	n	ipsilateral lung			
		V5	V20	V30	D _{mean}
40 keV	8	48.75 ± 12.90	31.03 ± 7.11	21.35 ± 7.53	1596.26 ± 444.05
60 keV	8	52.36 ± 14.22	33.55 ± 8.97	24.12 ± 9.62	1690.15 ± 483.26
80 keV	8	49.78 ± 13.37	30.78 ± 6.93	21.33 ± 7.65	1590.93 ± 453.13
100 keV	8	50.00 ± 13.09	31.73 ± 7.03	21.88 ± 7.26	1618.33 ± 434.29
120 keV	8	50.42 ± 13.43	31.61 ± 7.39	22.06 ± 7.86	1619.09 ± 446.40
140 keV	8	50.19 ± 13.28	31.61 ± 7.08	21.86 ± 7.52	1616.73 ± 427.58
<i>Fvalue</i>		0.063	0.136	0.136	0.050
<i>Pvalue</i>		0.997	0.983	0.983	0.998

Comparing the doses of 6 groups of the ipsilateral lung, $P > 0.05$, which means the difference was not statistically significant. Among them, the doses of V₅, V₂₀, V₃₀, and D_{mean} in the affected side of the 60 keV group were the largest, and the differences from the minimum values were 6.89%, 8.26%, 11.57%, and 5.87%. The minimum doses of V₂₀, V₃₀ and D_{mean} all appeared in the 80 keV group, and the minimum dose of V₅ was 40 keV.

Table 5
Dose of intact lung

Groups	n	intact lung			
		V5	V20	V30	D _{mean}
40 keV	8	28.69 ± 17.93	4.43 ± 6.26	0.51 ± 0.73	426.29 ± 258.48
60 keV	8	30.81 ± 16.46	4.20 ± 6.03	0.43 ± 0.60	443.93 ± 242.39
80 keV	8	29.94 ± 17.58	4.22 ± 6.12	0.47 ± 0.65	430.74 ± 263.37
100 keV	8	30.59 ± 17.62	4.39 ± 6.72	0.39 ± 0.57	437.08 ± 263.85
120 keV	8	30.78 ± 18.20	4.40 ± 6.62	0.48 ± 0.67	439.06 ± 270.72
140 keV	8	30.67 ± 17.68	4.12 ± 5.88	0.45 ± 0.60	438.25 ± 245.54
<i>Fvalue</i>		0.018	0.003	0.036	0.005
<i>Pvalue</i>		1.000	1.000	0.999	1.000

It can be seen from Table 5 that, similar to the ipsilateral lung, the dose data of the six groups of the healthy lung was compared, the result is $P > 0.05$, so the difference was not statistically significant. Among them, the ipsilateral lungs in the 40 keV group had the largest V_{20} and V_{30} , while V_5 and D_{mean} were the smallest. In the 60 keV group, the ipsilateral lungs had the largest V_5 and D_{mean} . The minimum values of V_{20} and V_{30} appeared in the 140 keV and 100 keV groups, respectively. And the differences from the minimum values were 6.88%, 7.00%, 23.53% and 3.97%. The dose curve of the ipsilateral and healthy lungs is shown in Fig. 3(a,b,c,d).

(2) Comparison of cardiac and spinal doses

Compare the V_{30} , V_{40} , D_{mean} of the dose of the heart and the maximum dose D_{max} of the spinal cord respectively. The data are shown in Table 6. It can be seen that, for the spinal dose of the six groups, $P > 0.05$, for the V_{30} , V_{40} , and D_{mean} of the heart dose, $P > 0.05$. This shows that there is no statistically significant difference between the maximum dose of the spinal cord and that of the heart.

Table 6
Doses of heart and spinal cord

Groups	n	Heart			Spinal cord
		V_{30}	V_{40}	D_{mean}	D_{max}
40 keV	8	10.88 ± 12.36	4.38 ± 5.47	876.45 ± 647.14	3753.35 ± 658.89
60 keV	8	7.24 ± 10.28	2.53 ± 3.95	833.71 ± 638.26	3739.28 ± 656.60
80 keV	8	7.40 ± 10.06	2.50 ± 3.89	826.83 ± 636.88	3866.39 ± 566.94
100 keV	8	8.13 ± 10.03	3.06 ± 4.52	857.55 ± 638.26	3941.00 ± 823.45
120 keV	8	7.34 ± 9.17	2.55 ± 3.46	841.93 ± 622.25	3881.95 ± 815.38
140 keV	8	7.96 ± 10.06	2.90 ± 4.51	850.33 ± 642.91	3807.34 ± 680.48
<i>Fvalue</i>		0.136	0.219	0.008	0.099
<i>Pvalue</i>		0.991	0.969	1.000	0.992

From the Table 6 we can see that the maximum cardiac dose was in the 40 keV group, in which the differences from the minimum were 33.46%, 42.92%, and 5.66%, respectively. The minimum value of V_{30} was in the 60 keV group, and the minimum value of V_{40} and D_{mean} was in the 80 keV group. The maximum value of the spinal cord dose was 3941.00 ± 823.45 , which appeared in the 100 keV group, and the minimum value was 3739.28 ± 656.60 , and appeared in the 60 keV group. The difference between the maximum and minimum values was 5.12%. Cardiac and spinal cord dose curves are shown in Fig. 3(e,f).

In summary, there are slight differences in single-energy images of different energies obtained from spectral CT scans when they are used in the design of radiotherapy plans, which are expressed as: there are differences in the CT values of images obtained by different energies, but no significant impact on physicians target delineation. In terms of dose, when the radiotherapy plan is performed on CT images of different energies, the difference between HI and CI values of the target area is not statistically significant. The differences between the various dose indicators are not significant. For the comparison between groups, the target area dose difference is the smallest (maximum 4.49%). The difference between lung dose, heart dose and spinal dose is in 3.97% -42.92%, obviously, the difference is large, but these differences are not statistically significant.

3.5 Discussion

The interactions between X-rays and substances mainly include photoelectric effect, Compton effect and electron pair effect. The commonly used diagnostic X-ray energy in the clinic is between 30 ~ 200 keV [16]. In this energy band, the photoelectric effect is dominant, and the mode of interaction depends on the characteristics of the substance itself and the X-ray energy. The lower the energy, the stronger the ability to distinguish substances [17]. Based on this characteristic, the traditional CT imaging method is attenuation imaging. The current CT image reconstruction algorithms include: filtered back projection algorithm, iterative reconstruction algorithm and direct Fourier back projection algorithm. Dual-energy computed tomography (DECT) reconstruction methods mainly include pre-processing method, post-processing method and iterative method [18]. Image reconstruction method is an influencing factor of image error.

Jiang Jie et al. [19] studied the diagnosis of chest diseases using dual-source CT virtual plain scan technology. Their results showed that the image quality of the virtual plain scan was not statistically different from that of the conventional plain scan. But for the display of partial calcifications and small lymph nodes near the vena cava, the plain scan group is superior to the virtual plain scan. Yan Zhaoxian et al.[20] studied the image quality of head and neck dual-energy low-dose radiation and found that compared with conventional doses, the signal-to-noise ratio (SNR) and image quality scores of the low-dose group images were not statistically significant. Zhang Xintang et al. [21] compared the enhanced images of lung cancer obtained by dual-energy scanning and conventional scanning, and found that the images obtained by the two scanning methods have no difference in the detection rate of the lesion and the detailed display of lobulation sign, burr sign, cavity, necrosis and so on. The studies above compared the difference between ordinary scanning and energy spectrum scanning imaging. Our research refines the difference in target area delineation caused by different reconstruction energy of energy spectrum scanning. The results show that the GTV volume difference obtained from the images of 6 groups of energy is not statistically significant.

Li Mingying et al. [22] believed that the lower the X-ray energy, the greater the absorption coefficient. The more X-ray attenuation, the better the CT value at 40 keV reflects the nature of the substance. The CT value of tumor tissue of lung adenocarcinoma and squamous cell carcinoma decreases with the increase of energy. This trend is consistent with the results of this study. Yan Zhaoxian et al. [20] believed that

there was no difference in the CT values of blood vessels obtained by different doses of CT imaging. Mitchell et al. [23] used phantom scanning and theoretical calculations to find that as the energy changes between 40 and 120 keV, the CT root-mean-square error varies between 6 HU and 248 HU, Especially for the combination of low energy and high atomic number, the difference is more obvious. In this study, the maximum CT value difference was within the GTV of the 40 keV group, reaching 231HU. Qi Zhenyu et al [24] showed that the scanning voltage, CT bed surface and geometric position of the phantom are all influencing factors of CT value. In this study, the CT values of GTV, heart and spinal cord tissues all decreased with increasing energy. The significant difference in CT value did not have a significant impact on the volume of the GTV outlined by the physician. The author believes that this may be related to the recognition ability of the human eyes. Under the condition of a specific window width and window level, if the gray difference between adjacent areas is less than $I_{Max} / 16$, it is difficult for the human eye to distinguish [25]. With the development of artificial intelligence, automatic contouring technology has received extensive attention [26]. The contouring technology based on CT values will inevitably place higher demands on the accuracy of the CT values of the images.

The dose calculation of the radiotherapy planning system depends on the CT value-electron density curve. The CT value obtained from the phantom scan under specific scanning conditions and the electronic density value provided by the manufacturer are input during data configuration. Gao Liquan et al [27] used different CT-electron density conversion curve, the difference of MU values obtained by different plans are all < 20%, of which the intensity modulation plan is larger. In recent years, scholars have done a lot of research on the relationship between CT value and electron density curve. A lot of research has been done [28–32]. Qin Jiaojiao et al proposed a spectral CT electron density image reconstruction technology based on multi-material decomposition algorithm. Numerical simulation experiment results It is shown that the electron density image reconstructed by this algorithm can easily and intuitively distinguish four substances: water, ethanol, glycerol and plexiglass, and the internal structure information of the image is more abundant. This indicates that the spectral CT is used for both diagnosis and radiation therapy. There is huge potential.

4 Conclusions

In this study, under different reconstruction energies, the CT value of the same tissue is different, which in turn causes the difference in radiotherapy dose. Since our study uses the same CT value-electron density curve, the accuracy of the calculation of each energy dose still needs to be further improved. In the following work, future research in this area can be refined in order to provide a reference for the selection of scanning conditions for precision radiotherapy.

Abbreviations

CT
Computer Tomography
OARs

organs at risk
PTV
planning target volume
GTV
gross tumor volume
HI
homogeneity index
CI
conformity index
NSCLC
Non-small cell Lung Cancer
CTV
clinical target volume
IMRT
intensity modulated radiation therapy
DECT
Dual-energy computed tomography
SNR
signal-to-noise ratio

Declarations

Ethical Approval and Consent to participate

This study was approved by the institution Ethics Commission of The First Affiliated Hospital of Shandong First Medical University. The need for consent to participate was waived by Ethics Commission of The First Affiliated Hospital of Shandong First Medical University.

Consent for publication

Written informed consent was obtained from each patient.

Availability of supporting data

Please contact authors for data requests.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Yong Hou made substantial contributions to the conception design of the work. Tian Xiufang was a major contributor in writing the manuscript. Liu Kun and Zhang Jian Dong substantively revised the manuscript. Wang Jing analyzed the data and created figures using data. All authors read and approved the final manuscript.

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Figures

Figure 1

Graphs of CT values for different tissues under different energies

Figure 2

CT images of different energies on the same level (W / L: 400/40) Note: The energy represented by serial numbers 1-6 are 40keV, 60keV, 80keV, 100keV, 120keV, 140keV

Figure3(a) V5 of the lungs

Figure3(b) V20 of the lungs

Figure3(c) V30 of the lungs

Figure3(d) Mean dose of the lungs

Figure 3(e) V30 and V40of the heart dose

Figure 3 (f) Mean dose of the heart and maximum dose of the spinal cord

Figure 3

Dose of organ at risk