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FULL PAPER

Evaluation of lung cancer by enhanced dual-energy CT: association between three-dimensional iodine concentration and tumour differentiation

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Objective: To investigate the correlation between iodine concentration of dual-energy CT (DECT) and histopathology of surgically resected primary lung cancers.

Methods: We reviewed the medical records, post-operative pathological records and pre-operative DECT images of patients who underwent surgical lung resection for primary lung cancer. After injection of iodinated contrast media, arterial and delayed phases were scanned using 140- and 80-kV tube voltages. Three-dimensional iodine concentration (iodine volume) of primary tumours was calculated using lung nodule application software.

Results: A total of 60 patients (37 males and 23 females; age range, 39–84 years; mean age, 69 years) with 62 lung cancers were analysed. The resected tumours were histopathologically classified into well-differentiated (G1; $n = 20$), moderately differentiated (G2; $n = 29$), poorly differentiated (G3; $n = 9$) and undifferentiated (G4; $n = 4$)

groups by degree of tumour differentiation (DTD). The mean $\pm$ standard deviation of iodine volume at the delayed phase was 59.6 ± 18.6 HU in G1 tumours, 46.5 ± 11.3 HU in G2 tumours, 34.3 ± 15.0 HU in G3 tumours and 28.8 ± 6.4 HU in G4 tumours; significant differences were observed between groups ($p < 0.001$). Univariate logistic regression analysis showed that iodine volumes both at the early and delayed phases were significantly correlated with DTD ($p = 0.006$ and $p = 0.001$, respectively), whereas gender, body weight and tumour size were not ($p = 0.084$, $p = 0.062$ and $p = 0.391$, respectively).

Conclusion: The iodine volume of lung cancers was significantly associated with their DTD. High-grade tumours tended to have lower iodine volumes than low-grade tumours.

Advances in knowledge: Iodine volume measured by DECT could be a valuable functional imaging method to estimate differentiation of primary lung cancer.

INTRODUCTION

Lung cancer is one of the most common malignancies worldwide and includes a variety of histological subtypes. The prognosis and malignancy of lung cancer are affected by pathology, including degree of tumour differentiation (DTD); high-grade tumours are associated with poorer prognoses.^{1,2} Therefore, pre-operative imaging is important for selecting the best therapeutic strategy. For pre-operative evaluation, ¹⁸F-fludeoxyglucose (FDG) positron emission tomography/CT (PET/CT) associated with tumour glucose metabolism has been widely used to determine invasiveness and to make prognostic predictions in patients with lung cancer.^{3–6}

Contrast-enhanced CT has also been used for functional imaging to evaluate intratumoral necrosis, vascularity and fibrosis, which are associated with invasiveness and prognosis.^{7–12} In the past, both non-contrast and contrast CT

were required to quantify contrast enhancement of a tumour. However, recently, a dual-energy CT (DECT) technique using two types of tube voltage has enabled quantification of the iodine-related attenuation of iodinated contrast material in the tumour after intravenous injection without the need for an additional unenhanced CT scan.^{13–15} Furthermore, novel computer application software (syngo® lung nodules application; Siemens Healthcare, Tokyo, Japan) attached to a DECT scanner can automatically evaluate a three-dimensional segment of a tumour and calculate iodine-related concentration (iodine volume) of the entire tumour.¹⁶ This computer-aided segmentation can decrease measurement error by manually illustrating the region of interest (ROI) in the tumour.

In this study, we reviewed pre-operative data from contrast CT with dual-energy scanning as well as post-operative

histopathological findings of primary lung cancers that were surgically resected and evaluated the association between these results.

METHODS AND MATERIALS

This retrospective study was approved by the institutional review board of Nagoya University Hospital (Number 2014-0384) with a waiver of informed consent for retrospective data analysis of patients with surgically and histologically confirmed lung cancer who underwent DECT for a clinical indication at our institution.

Patient selection

We reviewed the medical records, post-operative pathological records and pre-operative DECT images of patients who underwent surgical lung resection for primary lung cancer at Nagoya University Hospital between April 2014 and September 2014. Benign and metastatic tumours were excluded from this study. Non-solid types of lung cancer that were invisible on mediastinal window settings for thoracic CT were excluded. Patients who received pre-operative chemoradiotherapy were also excluded. We recorded patient characteristics (age and body weight) from medical records and tumour characteristics (histological type, DTD and pathological stage) from pathological records. Herein, the DTD was classified into the following groups: G1, well differentiated; G2, moderately differentiated; G3, poorly differentiated; and G4, undifferentiated (large cell carcinoma and small-cell carcinoma). For patients in whom FDG PET/CT had been performed pre-operatively at our institution, the maximal standard uptake value (SUV_{max}) was also recorded from the PET/CT report.

Dual-phase contrast-enhanced CT scan protocol

The dual-phase dynamic CTs were performed routinely to pre-operative evaluation of tumour and pulmonary vessels in our

institution. This pre-operative CT scan protocol was approved as a routine scan by an institutional conference comprised respiratory medicine, thoracic surgery and radiology.

All CT scans were performed with a dual-source CT scanner (Somatom® Definition Flash; Siemens Healthcare) in the craniocaudal direction with inspiratory apnoea. Vascular access was achieved *via* a cubital vein with a 20-G needle. For vessel enhancement, 96 ml of non-ionic contrast medium (ProScope 300, 300 mgI/ml Iopromide; Alfresa Pharma, Osaka, Japan, Optiray 320, 320 mgI/ml Ioversol; Tyco Healthcare, Tokyo, Japan or Iopamiron® 370, 370 mgI/ml Iopamidol; Bayer Healthcare, Tokyo, Japan) were used with flow rates of 4.0 ml s^{-1} . Iopromide was used for patients with body weights $<40 \text{ kg}$, ioversol was used for patients with body weights $40\text{--}59 \text{ kg}$ and iopamidol was used for patients with body weights $\geq 60 \text{ kg}$. The injection was immediately followed by a saline chaser bolus of 20 ml at the same flow rate using a dual-barrel power injector (Dual Shot GX7; Nemoto Kyorindo, Tokyo, Japan).

For the early phase, the scan delay was evaluated by an automatic bolus tracking system with a circular ROI localized on the descending aorta at the level of tracheal bifurcation. Scanning started automatically as the attenuation of the ROI increased 70 HU from baseline. The early phase has been routinely scanned for pre-operative evaluation of pulmonary vessels by three-dimensional pulmonary angiography. For the delayed phase, the scan delay was 90 s after the end of the early-phase scan. A dual-energy scan system (Tube A at a peak voltage of 140Sn kVp and Tube B at a peak voltage of 80 kVp) was used for both scans with collimation, $128 \times 0.6 \text{ mm}$; gantry rotation speed, 285–330 ms. Data were reconstructed with a slice thickness of 1.0 mm at 1.0-mm

Figure 1. Procedure for measuring the iodine volume of lung lesions. (a) At the delayed phase of contrast-enhanced CT, a solid-type adenocarcinoma is observed in the right upper lobe (arrow). (b) Iodine-enhanced images at the same level as shown in (a). (c) Three-dimensional measurement of the iodine value on an iodine-enhanced image. Automatic segmentation (double yellow line) and calculation of iodine volume can be performed using the “Lung Nodule” application of dual-energy CT. (d) Coronal view of iodine-enhanced image after segmentation.

increments using iterative reconstruction techniques (SAFIRE; Siemens Healthcare).

Analysis of dual-energy CT images

The three-dimensional iodine attenuation (iodine volume) of the primary lesion was measured using the syngo lung nodules application accessory software. This application can automatically calculate the iodine volume of pulmonary nodules with a three-material decomposition algorithm from DECT data sets (Figure 1). A chest radiologist who had 20 years' experience reading thoracic CTs segmented the primary tumour, measured the maximum diameter and recorded the iodine volume for the early and delayed phases. To reduce the effect of body weight and iodine concentration of contrast medium, corrected iodine volume values were calculated as follows:

Corrected iodine volume

$$= \frac{\text{Iodine volume [HU]}}{\text{Concentration of contrast medium [mgI]/Body weight [kg]}}$$

Statistical analyses

Among the four DTD groups (G1 to G4), possible differences in patient characteristics were compared. Gender was compared by χ^2 test, and the age, body weight, tumour size and iodine volume were compared by single-factor analysis of variance. Furthermore, between high (370 mgI) and low (300 or 320 mgI) concentration of contrast medium, possible differences in patient characteristics were compared. DTD was compared by Mann–Whitney's *U* test, and the body weight and iodine volume were compared by Student's *t*-test.

To compare each patient's characteristics with DTD (G1 and G2 vs G3 and G4), univariate logistic regression analysis was used. In addition, stepwise logistic regression analysis was used for multivariate analysis. Among the DTD groups, possible differences in patient characteristics of adenocarcinoma and of male patients were also compared.

To assess the association between the SUV_{max} on PET/CT and iodine volume at the early and delayed phases, Pearson's correlation coefficient was calculated. Analyses were performed using commercial statistical software: Excel® 2010 (Microsoft Corp., Redmond, WA) and SPSS v. 21 (IBM Corp., Armonk, NY; formerly SPSS Inc., Chicago, IL). A *p*-value <0.05 was considered statistically significant.

RESULTS

A total of 78 resected pulmonary lesions were reviewed, and 16 lesions were excluded (Figure 2). One case of hilar squamous cell carcinoma failed to segment with the syngo lung nodules application because it invaded extensively into the mediastinum. Finally, 62 consecutive primary lung cancer lesions from 60 patients were selected for analysis [37 males and 23 females; median age, 69 years (range, 39–84 years); median body weight, 60.5 kg (range, 39–85 kg)]. Based on the body weight, iopromide was used for 1 patient, Ioversol was used for 28 patients and iopamidol was used for 31 patients. Maximum tumour diameter ranged from 9 to 62 mm (median, 27.5 mm). Of these lesions, 43 were pathological Stage I, 8 were Stage II, 10 were Stage III and 1 was Stage IV. Associations between histological type and DTD are summarized in Figure 2. The mean $\pm$ standard deviation (SD) of iodine volume was 40.0 ± 21.4 HU in the early phase and 47.8 ± 17.2 HU in the delayed phase. The iodine volume between the early and delayed phases showed a significant correlation [Pearson's correlation coefficient (*r*) = 0.699, $p < 0.001$]. The mean $\pm$ SD of corrected iodine volume was 6.6 ± 3.4 HU in the early phase and 7.9 ± 2.4 HU in the delayed phase.

Table 1 compares patient characteristics among DTD groups. A significant difference was observed in male/female ratio: G1 tumours were more common in females ($p = 0.002$). The iodine volume both at the early phase and the delayed phases was significantly different among the four DTD groups ($p = 0.009$ and $p < 0.001$, respectively). G3 and G4 tumours had lower iodine

Figure 2. Study cohort flow chart. A total of 78 surgically resected pulmonary lesions were scanned pre-operatively with dual-phase contrast-enhanced CT using a dual-source technique. After exclusion, 62 primary lung cancers were included in the present analysis.

Table 1. Comparison of patient characteristics among differentiation grade groups

DTD	G1	G2	G3	G4	<i>p</i> -value
Male/female (n)	6/14	22/7	7/2	4/0	0.002
Age (years)	69 ± 7	66 ± 7	67 ± 11	65 ± 10	0.790
Body weight (kg)	57.6 ± 13.5	57.9 ± 8.9	64.3 ± 8.3	63.5 ± 6.6	0.300
Tumour size (mm)	24.5 ± 8.1	30.6 ± 11.6	27.6 ± 12.4	38.8 ± 9.2	0.060
Iodine volume (HU)					
Early phase	48.0 ± 19.6	42.2 ± 22.3	23.8 ± 13.7	21.8 ± 4.1	0.009
Delayed phase	59.6 ± 18.6	46.5 ± 11.3	34.3 ± 15.0	28.8 ± 6.4	<0.001
Corrected iodine volume (HU)					
Early phase	7.6 ± 2.4	7.1 ± 4.0	4.1 ± 2.2	3.9 ± 2.9	0.017
Delayed phase	9.6 ± 2.1	7.8 ± 1.8	6.0 ± 2.3	5.1 ± 1.4	<0.001

DTD, degree of tumour differentiation.

volume values than G1 and G2 tumours. For age, body weight and tumour size, no significant differences were observed among the four groups ($p = 0.790$, $p = 0.300$ and $p = 0.060$, respectively).

Table 2 compares patient characteristics among DTD groups in patients with adenocarcinoma. The iodine volume at the delayed phase was significantly different among the three DTD groups ($p = 0.002$). Higher-grade tumours had lower iodine volume values than lower-grade tumours. Furthermore, a significant difference in male/female ratio was observed among groups ($p = 0.021$). For age, body weight, tumour size and iodine volume at the early phase, no significant differences were observed among the three groups of adenocarcinoma ($p = 0.519$, $p = 0.360$, $p = 0.240$ and $p = 0.077$, respectively).

Table 3 compares patient characteristics among DTD groups in male patients. Only the iodine volume at the delayed phase showed significant differences among the four DTD groups ($p = 0.013$). For age, body weight, tumour size and iodine volume at the early phase, no significant differences were observed among the four groups in male patients ($p = 0.480$, $p = 0.157$, $p = 0.479$ and $p = 0.113$, respectively).

Table 4 compares patient characteristics between high and low concentration of contrast materials. The body weight of high-concentration group showed significantly heavier than that of low-concentration group ($p < 0.001$). For frequency of DTD, no significant differences were observed ($p = 0.773$). Iodine volumes both at the early and delayed phases of high-concentration group were significantly lower than those of low-concentration group ($p = 0.021$ and $p = 0.003$, respectively). On the other hand, for the corrected iodine volumes both at the early and delayed phases, no significant differences were observed between high- and low-concentration contrast medium ($p = 0.291$ and $p = 0.177$, respectively).

Table 5 shows the results of univariate logistic analysis for features associated with DTD of G3 and G4. Iodine volumes both at the early and delayed phases were significantly correlated with DTD ($p = 0.006$ and $p = 0.001$, respectively). Correlated iodine volumes both at the early and delayed phases were also significantly correlated with DTD ($p = 0.007$ and $p = 0.001$, respectively). The type of contrast medium was significantly correlated with DTD ($p = 0.0498$). On the other hand, gender, body weight and tumour size were not ($p = 0.084$, $p = 0.062$ and

Table 2. Comparison of adenocarcinoma patient characteristics among differentiation grade groups

DTD	G1	G2	G3	<i>p</i> -value
Male/female (n)	6/14	16/7	5/2	0.021
Age (years)	69 ± 7	66 ± 8	65 ± 12	0.519
Body weight (kg)	57.6 ± 13.5	56.2 ± 8.1	62.9 ± 8.9	0.360
Tumour size (mm)	24.5 ± 8.1	30.2 ± 12.8	29.1 ± 13.6	0.240
Iodine volume (HU)				
Early phase	48.0 ± 19.6	42.3 ± 22.7	26.9 ± 13.9	0.077
Delayed phase	59.6 ± 18.6	48.0 ± 11.3	35.6 ± 16.8	0.002
Corrected iodine volume (HU)				
Early phase	7.2 ± 2.9	7.0 ± 4.0	4.6 ± 2.2	0.197
Delayed phase	9.6 ± 2.1	7.9 ± 1.9	4.6 ± 2.1	<0.001

Table 3. Comparison of male patient characteristics among differentiation grade groups

DTD	G1	G2	G3	G4	<i>p</i> -value
Number	6	22	7	4	NA
Age (years)	71 ± 6	68 ± 6	70 ± 3	65 ± 10	0.480
Body weight (kg)	68.2 ± 13.0	60.5 ± 8.3	66.9 ± 4.7	63.5 ± 6.6	0.157
Tumour size (mm)	28.2 ± 6.6	30.4 ± 11.4	30.9 ± 12.2	38.8 ± 9.2	0.479
Iodine volume (HU)					
Early phase	39.6 ± 25.4	41.4 ± 22.8	22.6 ± 14.0	21.8 ± 4.1	0.113
Delayed phase	47.7 ± 18.0	44.6 ± 9.9	31.3 ± 14.9	28.8 ± 6.4	0.013
Corrected iodine volume (HU)					
Early phase	7.1 ± 3.4	7.2 ± 4.2	4.1 ± 2.4	3.9 ± 0.9	0.138
Delayed phase	8.6 ± 2.3	7.7 ± 1.6	5.7 ± 2.5	5.1 ± 1.4	0.009

DTD, degree of tumour differentiation. NA, not available.

$p = 0.391$, respectively). Stepwise logistic regression analysis revealed that of the six characteristics (gender, body weight, contrast medium, tumour size, corrected iodine volume at the early and delayed phases), only the corrected iodine volume at the delayed phase was significantly correlated with DTD (odds ratio, 0.450; 95% confidence interval, 0.269–0.751; $p = 0.002$).

Overall, 27 (43%) of 62 patients underwent PET/CT at our institution. The mean ± SD value of SUV_{max} on PET/CT was 6.0 ± 4.2 . The SUV_{max} was negatively correlated with iodine volume at the delayed phase by Pearson's correlation coefficient ($r = -0.594$, $p < 0.001$), although it was not significantly correlated with iodine volume at the early phase

($r = -0.297$, $p = 0.088$). Figures 3 and 4 show the representative DECT and PET/CT findings.

DISCUSSION

The results of the present study revealed that the iodine volume of primary lung cancer on dual-phase dynamic DECT was significantly correlated with DTD. High-grade tumours (G3 and G4) tended to have lower iodine volumes than low-grade tumours, particularly at the delayed phase. Additionally, the iodine volume at the delayed phase was negatively correlated with SUV_{max} on PET/CT: the lower the iodine volume, the higher the SUV_{max} . Previous studies^{17,18} showed that the SUV_{max} is significantly correlated with a tumour's malignant potential, invasiveness and DTD. Therefore, the significant correlation between the iodine volume and SUV_{max} observed in the present study provides further support of the iodine volume representing the DTD. To the best of our knowledge, this study is the first report that demonstrated the correlation between DTD and enhancement for primary lung cancer by DECT technique.

The negative correlation between iodine volume and DTD may be primarily caused by tumour necrosis. As intratumoral necrosis is usually recognized as unenhanced areas on enhanced dynamic CT, some necrotic but non-cavitary lung carcinomas show low attenuation.^{8,19} Both small-cell carcinomas and large cell neuroendocrine carcinomas, which are classified as grade 4, often include large areas of necrosis.²⁰ Poorly differentiated (G3) adenocarcinomas and squamous cell carcinomas also have increased necrosis.⁹ Therefore, higher-grade (G3 and G4) lung cancers tend to have lower iodine volumes on contrast-enhanced CT. Since tumour necrosis and DTD are independent and significant prognostic factors in non-small-cell lung carcinoma,^{21–23} iodine volume might be associated with prognosis. The enhancement of lung adenocarcinoma is also modified by intratumoral fibrosis, which is correlated with invasiveness and prognosis, and tumours with abundant internal fibrosis tend to show weak enhancement.⁷ Furthermore, Xiong et al¹² reported that CT perfusion characteristics including blood flow, blood volume and peak enhancement intensity are negatively

Table 4. Comparison of patient characteristic between two types of contrast medium

Contrast medium	300 mgI iopromide, 320 mgI ioversol	370 mgI iopamidol	<i>p</i> -value
Number	30	32	NA
Body weight (kg)	50.0 ± 5.2	67.6 ± 6.2	<0.001
DTD (n)			
G1/G2/G3/G4	11/16/2/1	9/13/7/3	0.773
Iodine volume (HU)			
Early phase	46.3 ± 20.3	33.8 ± 20.9	0.021
Delayed phase	54.4 ± 19.0	41.6 ± 12.6	0.003
Corrected iodine volume (HU)			
Early phase	7.1 ± 2.9	6.2 ± 3.9	0.291
Delayed phase	8.4 ± 2.5	7.5 ± 2.2	0.177

DTD, degree of tumour differentiation; NA, not available.

Table 5. Univariate logistic analysis for features associated with differentiation grades G3 and G4

Variables	Odds ratio	95% CI (min–max)	<i>p</i> -value
Gender (<i>vs</i> female)	4.125	0.825–20.624	0.084
Body weight (kg)	1.061	0.997–1.130	0.062
Contrast medium (<i>vs</i> iopamidol)	0.244	0.060–0.999	0.0498
Tumour size (mm)	1.024	0.970–1.082	0.391
Iodine volume (HU)			
Early phase	0.930	0.884–0.979	0.006
Delayed phase	0.883	0.818–0.952	0.001
Corrected iodine volume (HU)			
Early phase	0.646	0.471–0.887	0.007
Delayed phase	0.456	0.281–0.739	0.001

CI, confidence interval.

correlated with tumour differentiation based on the density of immature microvessels.

In the present study, the percentage of females with low-grade tumours, particularly well-differentiated adenocarcinomas, was significantly higher than that with high-grade tumours. Previous epidemiological studies^{24–27} revealed that female patients, especially non-smokers, are likely to have well-differentiated adenocarcinoma compared with male patients. As a result, the mean weight among patients with G1/G2 tumours was lighter than for patients with G3/G4 tumours, although no significant difference was observed. However, univariate logistic regression analysis showed a significant correlation between DTD and iodine volume, but not for gender or body weight. Based on these results, we concluded that iodine volume, particularly at the delayed phase, on enhanced dynamic CT primarily reflects the DTD.

While the SUV_{max} on PET/CT was significantly correlated with the iodine volume at the delayed phase, it was not significantly correlated with the iodine volume at the early phase. The enhancement at the early and delayed phases was not always

linear. At the early phase, the contrast agents are predominantly in the intravascular component, and the enhancement mainly reflects tumour blood flow. However, contrast enhancement primarily depends on extravascular–extracellular components at the delayed phase, and the enhancement reflects tumour necrosis and fibrosis. Because PET/CT scanning performed 1 h after administration of FDG reflects tumour activity rather than blood flow, the SUV_{max} would be more strongly associated with iodine volume at the delayed phase than at the early phase on dynamic CT. In addition, the noise caused by adjacent pulmonary vessels that are strongly enhanced at the early phase on dynamic CT might be associated with quantitative iodine volume.

In this study, only primary lung cancers resected surgically were reviewed because histopathological proof was necessary to compare the three-dimensional tumour enhancement on DECT. It is difficult for transbronchial lung biopsy and CT-guided transcutaneous needle biopsy which can only collect partial specimens of tumour to determine the DTD. Therefore, our cohort included relatively large numbers of Stage I and II lung

Figure 3. A 62-year-old female patient. (a) Well-differentiated (G1) adenocarcinoma is in the right upper lobe. (b) Iodine-enhanced image at the delayed phase of contrast-enhanced CT. The iodine volume is 57 HU. (c) Positron emission tomography/CT shows low fludeoxyglucose uptake of the tumour and the maximal standard uptake value is 1.1.

Figure 4. A 65-year-old male patient. (a) Poorly differentiated (G3) adenocarcinoma is in the right lower lobe. (b) Iodine-enhanced image at the delayed phase of contrast-enhanced CT. The iodine volume is 20 HU. (c) Positron emission tomography/CT shows high fludeoxyglucose uptake of the tumour and the maximal standard uptake value is 10.1.

cancers and this is a selection bias. Our results cannot be entirely generalized to all tumours especially advanced-stage cancers. For the resectable tumours, however, prediction of DTD correlated with a tumour's malignant potential, invasiveness on pre-operative diagnostic imaging is also important to decide therapeutic strategy, such as operative procedure and pre- or post-operative adjuvant treatment.

This retrospective study has three limitations. First, non-solid tumours, which consist largely of ground-glass opacity on thin-section CT, were excluded from our study cohort because it was difficult to automatically segment such hazy tumours using the software; this represents a selection bias. Non-solid tumours usually represent well-differentiated adenocarcinomas.³ Second, we used a fixed iodinated contrast agent volume rather than a patient body weight-determined contrast agent volume in this study, while contrast media of three iodine concentrations (300, 320 and 370 mgI) were assigned by body weight. This can result in lower enhancement in patients with heavier weight ≥ 60 kg. To reduce the effect of body weight and iodine concentration of contrast medium, therefore, we adopted the corrected iodine volume. Consequently, multivariate logistic analysis showed that

only the corrected iodine volume at the delayed phase of six characteristics including iodine concentrations of contrast medium was significantly correlated with DTD. However, further investigation using a patient body weight-determined contrast agent volume is also necessary to provide more definitive correlation between DTD and iodine volume. Third, PET/CT was performed for only 43% of all lesions at our hospital, because it was skipped for patients examined at other hospitals. Although SUV_{max} on PET/CT is an eminent index of tumour malignancy and activity, the cost of examination is more expensive than contrast-enhanced CT. If iodine volume on contrast-enhanced CT can substitute for PET/CT, it would be cost-effective for patients with lung cancer.

CONCLUSION

In conclusion, DECT can estimate three-dimensional tumour enhancement without non-contrast CT scanning. The iodine volume of primary lung cancers measured by contrast-enhanced CT was significantly associated with their degree of differentiation and FDG PET/CT findings. Low iodine volume at the delayed phase on dynamic CT implies a poorly differentiated or undifferentiated tumour.

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