Evaluation of Response to Stereotactic Body Radiation Therapy For Non-Small Cell Lung Cancer: PET Response Criteria in Solid Tumors (PERCIST) Versus Response Evaluation Criteria in Solid Tumors (RECIST)

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Research

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Abstract

Background: Recommendations for surveillance after stereotactic body radiation therapy (SBRT) for early stage non–small cell lung cancer (NSCLC) are not well defined. Recently, PET response criteria in solid tumors (PERCIST) have been proposed as a new standardized method to assess radiotherapeutic response both quantitatively and metabolically. The aim of this study was to evaluate therapeutic response following Stereotactic Body Radiotherapy in early-stage Non-Small Cell Lung Cancer patients by comparing PERCIST with the currently widely used RECIST.

Methods: Forty-nine patients with early-stage Non-Small Cell Lung Cancer who had been prescribed Stereotactic Body Radiotherapy were studied. Responses of lesion were evaluated using CT and 18F-FDG PET according to the RECIST and PERCIST methods. PET-CT scans were obtained before SBRT and 3 to 6 months after SBRT. Associations between overall survival and clinicopathologic results (histology, tumor location, tumor size, lymphatic invasion, clinical stage, radiotherapeutic responses in RECIST and PERCIST) were statistically analyzed. Median patient follow-up was 30 months.

Results: Thirteen patients had stage IA, 9 stage IB, 10 stage IIA, and 17 stage IIB biopsy-proven NSCLC. Three-year overall survival was 79.6%. CT scans indicated 3 regional recurrences. PET/d-chest indicated 3 regional recurrences and distant metastasis. Significant differences were observed in response classification between RECIST and PERCIST (Wilcoxon signed-rank test, P=0.0041). Uni-variate analysis showed that clinical stage, RECIST and PERCIST were significant factors associated with overall survival, whilst by multivariate analysis PERCIST was the only predictor of overall survival. SMD, PMD/PMR, CMR in PERCIST criteria was indicative of a 9.900-fold increase in the risk of overall survival in early NSCLC patients [RR 9.900 (95% CI 1.040, 21.591), P=0.001].

Conclusion: RECIST based on the anatomic size reduction rate did not demonstrate correlation between radiotherapeutic response and prognosis in patients with early-stage NSCLC receiving SBRT. However, PERCIST was shown as the strongest independent predictor of outcomes. PERCIST might be considered more suitable for evaluation of NSCLC tumour response to SBRT than RECIST.

Introduction

Lung cancer is the third most common cause of cancer and the leading cause of death in the world. Surgical resection is the treatment of choice for early-stage non-small cell lung cancer (NSCLC) with a 70% five-year survival and a 55-75% recurrence rate [1]. In patients who are medically inoperable or decline surgery, emerging evidence shows that Stereotactic body radiation therapy (SBRT) has become the preferred treatment option with a 70% five-year primary tumor control rate. The safety and efficacy of SBRT have been systematically evaluated in phase I and II clinical trials. Compared to conventional fractionated radiation therapy, SBRT has shown excellent response rates with improved local control and survival [2–6]. Currently both the National Comprehensive Cancer Network (NCCN) and the American Society for Therapeutic Radiology and Oncology (ASTRO) do not recommend surveillance protocol

guidelines for follow-up after SBRT for lung cancer, despite SBRT becoming increasingly established as a new standard of care for patients with medically inoperable early-stage NSCLC [6].

The Radiation Therapy Oncology Group (RTOG) 0236 trial followed patients with computed tomography (CT) every 3 months during the first 2 years after treatment, then every 6 months for 2 more years [6]. Tumour response was evaluated based on changes in tumor size, according to criteria proposed by the World Health Organization [7] or RECIST [8, 9]. However, RECIST is well known to have certain limitations where tumors that have obscure margins or scar tissue after treatment and in its utility to assess in-field recurrence.

PET-CT performed with the glucose analog ^{18}F-FDG has been established as an imaging modality for evaluation metabolic activity in oncology [10, 11]. The technique has been reported to be more informative compared to CT alone for the evaluation of treatment response after chemotherapy [12]. Recently, Min and Colleagues reported PET Response Criteria in Solid Tumors (PERCIST) as a new standardized method for the quantitative assessment of metabolic tumor response [13]. However, guideline of NSCLC does not routinely include the use of ^{18}F-FDG PET for evaluation of therapeutic response to SBRT in patients with NSCLC [14, 15] thus limiting its utility to assess in-field recurrence. Recently, several studies have demonstrated that FDG PET-CT performed 3 months following SBRT for NSCLC asan insensitive test for the evaluation of local recurrence and metastasis [16–20]. PERCIST should be properly evaluated with regard to advantages over RECIST in clinical cases have not been explored. In this study, we performed a retrospective review of the patients treated at our institution to compare the PERCIST and RECIST methods for evaluation of therapeutic response to SBRT in patients with early-stage NSCLC.

Materials And Methods

Ethics statement

All subjects were recruited to the study by informed consent. We protected patient privacy and excluded patient identification information from our analysis. The study was carried out according to the Helsinki Declaration and approves processed under approval of the written consent statement by Ethical Committee of the Sixth Medical Center of the General Hospital of the People's Liberation Army of China, Beijing, China.

Patients

Patients with early-stage NSCLC treated with curative intent during July 2015 to June 2018 at the Sixth Medical Center of the General Hospital of the PLA were included in the study. Specific criteria for inclusion criteria were 1) patient with NSCLC previously untreated, 2) undergoing curative treatment, pretreatment and 3–6 months post-treatment imaging with whole-body ^{18}F-FDG PET-CT and computed CT, and 3) complete follow-up of at least twenty-four months after completion of treatment. Those not eligible to be recruited to the study were patients with distant metastasis at initial staging and those

treated with palliative intent. Tumors were staged according to the tumor-node-metastasis (TNM) staging system of the American Joint Committee on Cancer (AJCC) [21]. Study protocols were reviewed and approved by the Institutional Review Board of the Sixth Medical Center of the General Hospital of the People's Liberation Army of China and the informed consent required from each patient was waived.

SBRT Delivery

All stereotactic body radiation therapy (SBRT) treatments were delivered at our institution on a CyberKnife Robotic Stereotactic Radiosurgery System (Accuray, Inc, Sunnyvale, Calif). Patients were positioned for treatment in a body-length vacuum cushion with arms down for comfort. Treatment planning was done with non-contrast chest CT performed in the radiology department on a GE Lightspeed 64 Slice CT scanner (GE Medical Imaging, Waukeshka, Wis). Images were imported into the MultiPlan CyberKnife treatment planning system (Accuray, Inc, Sunnyvale, Calif). Gross tumor volume was defined by the treating radiation oncologist and thoracic surgeon as the tumor visible on lung windowed CT scan. A margin of at least 5 mm was added to the gross tumor volume to define the planning target volume. Relevant critical structures including lungs, spinal cord, proximal bronchial tree, esophagus were also defined. Treatment plans were formulated to treat at least 95% of the planning target volume with 50 to 60 Gy in 5 to 8 fractions with the biologically equivalent dose greater than 100 Gy for every treatment course. The first 24 treatment plans were calculated with the Ray-Tracing algorithm, and the subsequent 11 were calculated with the Monte Carlo algorithm. Prescription isodose lines were between 60% and 90%. Radiation dose to critical structures was limited to acceptable and safe levels specifically. All treatments were delivered with image guidance using implanted fiducial markers as surrogates for tumor location with the Synchrony Respiratory Tracking System (Accuray, Inc, Sunnyvale, Calif) used for all cases. Patients were pretreated with 4 mg of dexamethasone on days of treatment and SBRT treated on nonconsecutive days.

^{18}F-FDG PET/CT imaging and interpretation

Patients received whole-body ^{18}F-FDG PET-CT scans using a multi-slice PET-CT camera system (Discovery STE 8, GE Healthcare, Milwaukee, WI, USA) equipped with 16-, 40-, or 8-slice CT scanners. Blood glucose concentrations of all patients were <150 mg/dl before scanning. Whole-body images, generally from the top of the skull to mid thigh, were acquired about 60 mins after intravenous injection of ^{18}F-FDG at the dose of 3.7 MBq (0.10 mCi)/kg of weight. ^{18}F-FDG/CT scanning without contrast enhancement was performed in spiral mode from the skull to the proximal thigh for attenuation correction and image fusion followed by three-dimensional caudo-cranial PET scanning. The emission scan time per bed position was 2.5 mins and six or eight bed positions were used. The PET data were reconstructed using a standard iterative algorithm with attenuation correction based on the CT data. The PET-CT scans were obtained before SBRT and about 3-6 months after SBRT.

PET or PET-CT images by visual inspection were inspected and interpreted by a nuclear medicine physician. Foci with increased ^{18}F-FDG uptake in the primary tumours and metastatic nodes were

evaluated and compared with the background and blood pool activities. Image interpretation was based on visual and semi-quantitative analyses of abnormally increased focal ^{18}F-FDG uptakes but no strict standardized uptake value cutoffs were used. Local, regional, and distant sites were independently assessed and the presence of any primary site tumours, metastatic lymph nodes or soft tissues of the neck, and distant site of each patient were recorded.

Response Evaluation with PERCIST

PERCIST recommends the use of lean body mass for SUV normalization with no particular algorithm stated. SUV normalized to lean body mass is termed SUL. The background area was drawn as a 3-cm-diameter spheric region of interest (ROI) in the right lobe of the liver as defined in the criteria. In patients with liver involvement, the background area was drawn in the descending thoracic aorta. With the available software, it was not possible to extend the ROI from 1 to 2 cm in the z-axis as described in the criteria and it was drawn as a sphere 1-cm-diameter ROI.

The lesion with highest SUL was identified and a 1.2-cm-diameter spheric ROI was drawn in the hottest part of that lesion. The ROI was placed in the area of the tumor where it resulted in the highest possible mean SUL (SULmean). SULmean of this ROI was SULpeak. Baseline SULpeak had to exceed 1.5× liver SULmean + 2×SD of liver SULmean or 2×aorta SULmean + 2×SD of aorta SULmean for the tumor to qualify as a target lesion. It was checked that no other lesion could give a higher SULpeak. On subsequent scans, SULpeak could be located in a different lesion from the one measured at baseline, as long as the lesion had been present since baseline. If SULpeak at baseline did not exceed the background value, the patient was not eligible for response evaluation with PERCIST.

Response evaluation methods

Objective therapeutic responses according to RECIST 1.1 are as follows 1) complete remission (CR) is disappearance of target lesion for at least 4 WKS; partial remission (PR) is a decline of at least 30% in tumor diameter; stable disease (SD) is neither PR nor progressive disease (PD); and PD is at least a 20% increase in tumor diameter and 5-mm absolute increase was required. Objective therapeutic responses according to PERCIST 1.0 are as follows; 2) complete metabolic response (CMR) is complete resolution of ^{18}F-FDG uptake within the measurable target lesion so that it is less than mean liver activity and indistinguishable from surrounding background blood-pool levels with no new ^{18}F-FDG-avid lesions. Partial metabolic response (PMR) is reduction of a minimum of 30% in the target tumor ^{18}F-FDG SULpeak. Stable metabolic disease (SMD) is disease other than CMR, PMR, or progressive metabolic disease (PMD); and PMD is a 30% increase in ^{18}F-FDG SULpeak or advent of new ^{18}F-FDG-avid lesions that are typical of cancer.

Statistical Analysis

As new lesions noted on PET-CT were not used for progress in RECIST 1.1, to accurately compare PET-CT and CT in the evaluation of treatment response, new lesions which could not be found or confirmed on

routine CT were eliminated in RECIST and compared with PERCIST once more using the chi-square test. Overall survival (OS) was calculated using the Kaplan–Meier test and statistical significance tested evaluated by the log-rank test. Associations between survival and clinico-pathologic results including radiotherapeutic responses defined by changes of imaging parameters and pathologic factors, were evaluated using univariate Cox proportional hazards regression analysis for OS. Significant parameters identified by univariate analysis were included in a multivariate Cox proportional hazards regression analysis. All statistical analyses were performed using SPSS statistical package version 17.0 (SPSS Inc., Chicago, IL). A P value of 0.05 or less was considered statistically significant.

Results

Fundamental Data of Patients

Characteristics of all 49 patients included in this study are summarized in Tables 1 and 2. Blood glucose levels at each PET-CT study before and after 3 months radiotherapy were less than 149.6 mL/dL in all patients. There was almost no difference in uptake time between PET-CT before and after 3-6 months radiotherapy. The interval between PET-CT scans obtained before and after 3-6 months radiotherapy was 120 d ± 13 (mean ± SD). The interval between completion of radiotherapy and the acquisition of the PET-CT scan was about 3 mo (mean ± SD, 3.1 mo ± 0.3; range, 80-108 d). Lean body mass was calculated using body weight and height as shown in Table 2: before radiotherapy, 47.5 ± 8.9 kg (mean ± SD), and after 3 months radiotherapy, 47.2 ± 8.8 kg.

Table 1
Baseline patient characteristics

Characteristic	Patients (n = 49)	
	n	%
Gender		
Male/Female	10/39	20.4/79.6
Age		
>70y/ <70y	27/22	55.1/44.9
ECOG		
>2/≤2	34/15	69.4/30.6
Reason for inoperability		
Poor pulmonary function (FEV1 and/or DLCO<40%)	21	42.9
Other cardiopulmonary	15	30.6
Refusal of surgery	13	26.5
Tumor Size		
<3	25	51.0
3-5	16	32.7
>5	8	16.3
AJCC T Stage		
T1	23	46.9
T2	15	30.6
T3	11	22.5
TNM stage		
Ia t1	13	26.5
Ib t2	9	18.4
IIa t1n1	10	20.4
IIb t3 t2n1	17	34.7
Tumor location		
Central	8	16.3

Characteristic	Patients (n = 49)	
	n	%
Peripheral	41	83.7
pN		
pN-	33	67.3
pN+	16	32.7
Histology		
Adenocarcinoma	20	40.8
Squamous	25	51.0
NSCLC (NOS)	4	8.2

Table 2
Parameters Before and After SBRT for Non-small Cell Lung Cancer

Parameter	Before SBRT	Three months after SBRT
Blood glucose level (mg/dL)		
Mean±SD	102.1 ± 20.6	107.2 ± 22.3
Range	72-149	71-158
Body weight (kg)		
Mean±SD	63.2 ± 12.8	65.6 ±13.1
Range	38-90	37-89
Body height (kg)		
Mean±SD	160.8 ± 11.5	160.8 ± 11.5
Range	150-185	150-185
Uptake time (min)		
Mean±SD	62.3 ± 4.6	63.1±4.3
Range	53-70	56-70

Treatment Response Assessments in RECIST and PERCIST

Results from RECIST and PERCIST are summarized in Table 3. In RECIST, the longest diameter of the lesion was not available with CT from 21 patients as tumors were not visible on the CT images. In all patients, the reduction rate of the tumor diameter was 75.52 ± 28.75 (mean ± SD). Objective therapeutic responses according to RECIST 1.1 were as follows: 21 CR, 16 PR, 9 SD and 3 PD. On the other hand, according to PERCIST, the SULpeak on PET-CT was available for all 49 patients. The reduction rate of the SULpeak was 63.57± 28.40 (mean ± SD). Twenty-eight of the 49 tumors exhibited a low SULpeak (mean ± SD, 1.63 ± 1.51) after completion of radiotherapy, which was less than the liver background level (mean ± SD, 2.17 ± 0.31) and indistinguishable from surrounding background blood-pool levels. PET-CT of two patients revealed a decreased metabolic activity after radiotherapy (Figure 1). Thus, CMR was achieved in these 18 patients. Objective therapeutic responses according to PERCIST 1.0 were as follows: 16 CMR, 18 PMR, 8 SMD and 7 PMD. There was a significant difference in the results of response classification between RECIST and PERCIST (Table 4; P= 0.041).

Table 3
Therapy Response Assessments from RECIST and PERCIST

Criteria	**Radiotherapy**	
	Before SBRT	**Three months after SBRT**
RECIST		
Longest diameter (cm)	3.72±1.36	0.93±1.22
Reduction rate of tumor diameter (%)	75.52±28.75	
Objective therapeutic response		
CR/PR/SD /PD	21/16/9/3	
PERCIST		
Tumor SULpeak	4.49± 1.92	1.63± 1.51
Liver SUL = 2× (SD)	2.06 ± 0.23	2.17 ± 0.31
Reduction rate of tumor SULpeak (%)	63.57± 28.40	
Objective therapeutic response		
CMR/PMR/SMD/PMD	18/21/7/3	
Data are mean ± SD or n.		

Table 4
Comparison of Treatment Response Assessments in RECIST and PERCIST

RECIST	PERCIST				
	CMR	PMR	SMD	PMD	Total
CR	14	6	0	1	21
PR	3	9	2	2	16
SD	1	4	4	0	9
PD	0	2	1	0	3
Total	18	21	7	3	49
RECIST and PERCIST					

Table 5
Univariate analyses of various prognostic parameters in patients with NSCLC.

Characteristic	P value
Location	
Central/ Peripheral	0.150
T stage	
T1/T2/T3	0.259
N classification	
Positive/Negative	0.582
Clinical stage	
Ia, Ib/IIa,IIb	0.032
RECIST	
CR, PR/stable disease, PD	0.073
PERCIST	
CMR/PMR, SMD, PMD	0.00003

Radiotherapeutic Responses and Clinico-pathologic Factors Affecting Survival

Associations between survival and clinic-pathologic features (such as radiotherapeutic responses including changes of imaging parameters and pathologic factors) were assessed using univariate and multivariate Cox proportional hazards regression analyses (Table 6). Clinical stage and PERCIST were significant factors associated with OS in this study. Location, T stage, N classification and RECIST were not a significant prognostic factor (Table 6, Fig. 1), Kaplan-Meier curves showed that PERCIST was significant prognostic factor for predicting OS (Fig. 1). Multivariate Cox proportional hazards regression analysis demonstrated that PERCIST 1.0 (CMR/PMR vs. SMD/PMD) was the only significant prognostic factor for predicting OS (RR 9.900 95% CI 1.040, 21.591, P=0.001; Table 6) in the multivariate Cox proportional hazards regression analysis.

Table 6
Multivariate analyses of various prognostic parameters in patients with NSCLC.

	Multivariable analysis		
	P-value	Relative Risk	95% confidence interval
Location			
Central/ Peripheral	0.059	5.682	0. 938-34.416
T classification			
T1/T2/T3	0.102	4.119	0.754-22.487
N classification			
Positive/Negative	0.901	1.183	0.083-16.772
Clinical stage			
IIa, IIb/ Ia, Ib	0.313	4.736	0.231-97.254
RECIST			
SD, PD/ CR, PR	0.747	1.263	0.306-5.236
PERCIST			
SMD, PMD/ CMR, PMR	0.001	9.900	1.040, 21.591

Discussion

According to criteria proposed by the World Health Organization or RECIST criteria,the evaluation of tumor response is based on changes in tumor size [22, 23]. However, it is well known to have limitations in the cases with tumors that have obscure margins or scar tissue after treatment and in its utility to assess in-field recurrence. PERCIST—that is, RECIST using ^{18}F-FDG PET is considered to overcome such limitations as metabolic changes are closely related to malignant potential of tumors and thus may be the most accurate noninvasive imaging modality for initial staging and response assessment in lung

cancer, PERCIST has recently been proposed as a standardized method for evaluation of metabolic tumor response [24].

In present study, we performed a retrospective review of the 49 patients treated at our institution to compare the PERCIST and RECIST methods for evaluation of therapeutic response to SBRT in patients with early-stage NSCLC. Our data showed a significant difference in the results of response classification using RECIST and PERCIST. PERCIST was found to be the strongest independent predictor of outcomes in patients with early NSCLC receiving SBRT. To our knowledge, this is the first report demonstrating the correlation between therapeutic responses and prognosis in early NSCLC receiving SBRT compared PERCIST and RECIST.

SBRT has emerged as a way to reduce treatment volumes and to facilitate hypofractionation with delivery of large daily tumor doses. Prior to the wide acceptance of SBRT, conventionally fractionated radiation therapy was one of the available options for this patient cohort and provides benefit with median survival times about 1.5 years [25]. Recently, increasing evidence has shown SBRT has become the preferred treatment option with a 70% five-year primary tumor control rate in patients who are medically inoperable or decline surgery [2–6]. In our series of 49 patients treated with SBRT, the 3-year overall survival was 79.6% with a median survival time of 30 months. This is consistent with the results of previous prospective multicenter trials.

Surveillance follow-up after treatment is very important for early detection of locoregional recurrence and metastasis. The Radiation Therapy Oncology Group (RTOG) 0236 trial followed patients with computed tomography (CT) every 3 months during the first 2 years after treatment, then every 6 months for 2 more years [6]. Despite this protocol, many physicians in clinical practice utilize FDG PET-CT for surveillance follow up. Recently, there have been several reports [16–20] on the utility of response evaluation of radiotherapy with ^{18}F-FDG PET in early-stage NSCLC. FDG PET-CT, with 72-94% sensitive and 77-92% specific for evaluating malignancy in early-stage NSCLC, is superior to CT scan for detecting mediastinal metastasis with a sensitivity and specificity of 77% and 86%, respectively, despite the concern for increased FDG activity in areas of inflammation.

In our present study, there were no detected regional recurrences when follow-up evaluation was limited to CT alone. Three malignancies in lung nodules with 20% increase in tumor diameter were evaluated as PD by RECIST criteria. However, these nodules showed no metabolic activity by PET-CT. The addition of PET aided in the detection of 1 regional recurrence and 2 distant metastases in the same 49 patients. This result revealed that PERCIST was more sensitive in detection the CR and progression patients. There was a significant difference in the results of response classification between RECIST and PERCIST. This may be due to metabolic changes being closely related to malignant potential of tumors or that the maximum diameter of the tumor is not detectable with the resolution of CT. It is possible for omission of the primary lesions and the early pathological changes, of course the recurrences included.

We confirmed clinical stage to be univariate risk factors in the present study, whilst location, tumor T stage, node metastasis were not significant risk factors in our univariate analysis [26, 27]. These findings do not agree with previous reports that tumor T stage is risk factors for the outcome in early NSCLC patients [28] which may be due to the small size of study population.

PERCIST criteria was a univariate predictor of overall survival of early NSCLC, while RECIST was not significant risk factor in our univariate analysis. The relationship between the metabolic changes of tumors and prognosis has been reported in several studies and the data were controversial [12, 29, 30]. Yanagawa's and Colleagues reported that PERCIST (CMR vs. non-CMR) was the most significant prognostic factor for predicting DFS and OS in the multivariate Cox proportional hazards regression analysis in Esophageal Cancer [12]. Ding and colleagues demonstrated that only PERCIST was a significant factor for predicting DFS in NSCLC [29]. Contrastingly, Lee and colleagues showed that an early metabolic response did not translate into better survival outcome in advanced/metastatic NSCLC [30].

In agreement with predominant data currently available, our experimental data demonstrate PERCIST as a univariate predictor of overall survival of early NSCLC. Clinical stage was another univariate predictor of overall survival of early NSCLC in our study. However, clinical stage was not significant risk factors in our multivariate analysis. Interestingly, our results show that PERCIST was the only multivariate predictor of overall survival in early NSCLC patients. In fact, SMD, PMD/PMR, CMR in PERCIST criteria was indicative of a 9.900-fold increase in the risk of overall survival in early NSCLC patients [RR 9.900 (95% CI 1.040, 21.591), P=0.001]. Figure 1 demonstrates that SMD/PMD in PERCIST criteria was associated with overall survival in early NSCLC patients treating with SBRT.

Our present study showed PERCIST was considered to be better for evaluation of treatment response in early NSCLC patients treating with SBRT, which was closely related to prognosis. However, the problem of false positive deserves attention, inflammation of the target tissue, scar tissue after treatment, and so on may cause interference to the utility of response evaluation of radiotherapy with 18F-FDG PET.

The limitations of the current study should also be acknowledged. Firstly, this is a retrospective, single-center study with a small study population. Secondly, the follow-up time is relatively short to observe the overall survive. At the same time, PET-CT was performed at an early stage (3-6 months) after SBRT. At this stage, several study reports that inflammation after treatment showed high metabolism activity with high SUV on PET, may implicit false positive of tumor recurrence [31–33]. However, our present study showed PET aided in the detection of 1 regional recurrence and 2 distant metastases which was not in the field of treatment,exclusion of false positive. Finally, we evaluated the longest diameter of just 1 target lesion that was assessed in PERCIST.

Ideally, it might have necessary to evaluate 5 target lesions were evaluated in RECIST 1.1. However, as RECIST 1.1 suggests that just 3 lesions (not 5 lesions) may be used in randomized studies in which tumor progression is the major concern [10. 11], the number of lesions to evaluate when assessing

response to therapy may also be important in both RECIST and PERCIST. Further study from this viewpoint will be needed in the future.

Conclusions

In conclusion, this study demonstrates that PERCIST might be a more suitable method than RECIST for the evaluation of response of early-stage NSCLC to SBRT. PERCIST, a new standardized evaluation method that uses metabolic information from PET (a noninvasive imaging procedure) is expected to provide improved information for therapeutic strategy selection in cancer patients.

Abbreviations

PERCIST: PET Response Criteria in Solid Tumors; RECIST: Response Evaluation Criteria in Solid Tumors; SBRT: Stereotactic body radiation therapy; NSCLC: non–small cell lung cancer; 18 FDG-PET: 18Fluoro-deoxy-glucose positron emission tomography; CT: Computed tomography; NCCN: National Comprehensive Cancer Network; ASTRO: American Society for Therapeutic Radiology and Oncology; RTOG: Radiation Therapy Oncology Group; TNM: tumor-node-metastasis; AJCC: American Joint Committee on Cancer; ROI: region of interest; CR: complete remission; PR: partial remission; SD: stable disease; PD: progressive disease; CMR: complete metabolic response; PMR: Partial metabolic response; SMD: Stable metabolic disease; PMD: progressive metabolic disease; OS: Overall survival; DFS: Disease-free survival.

Declarations

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Authors’ contributions

Jixia Han wrote the manuscript. Rui Du, Henghu Fang, Zejun Lu and Jingbo Kang designed the research. Zejun Lu, Qi Song and Jixia Han participated in data collection. Qi Song conducted the statistical analysis. Feng Guo prepared the pictures presented in the figures. Zejun Lu critically revised the manuscript and were involved in data interpretation. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable.

Ethics approval and consent to participate

The ethics committee of the Sixth Medical Center of the General Hospital of the People's Liberation Army of China approved the study. The informed consent was exempted due to the retrospective nature of the study. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

All authors have approved the manuscript and agree with submission to Radiation Oncology.

Competing interests

The authors declare no conflicts of interest.

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Figures

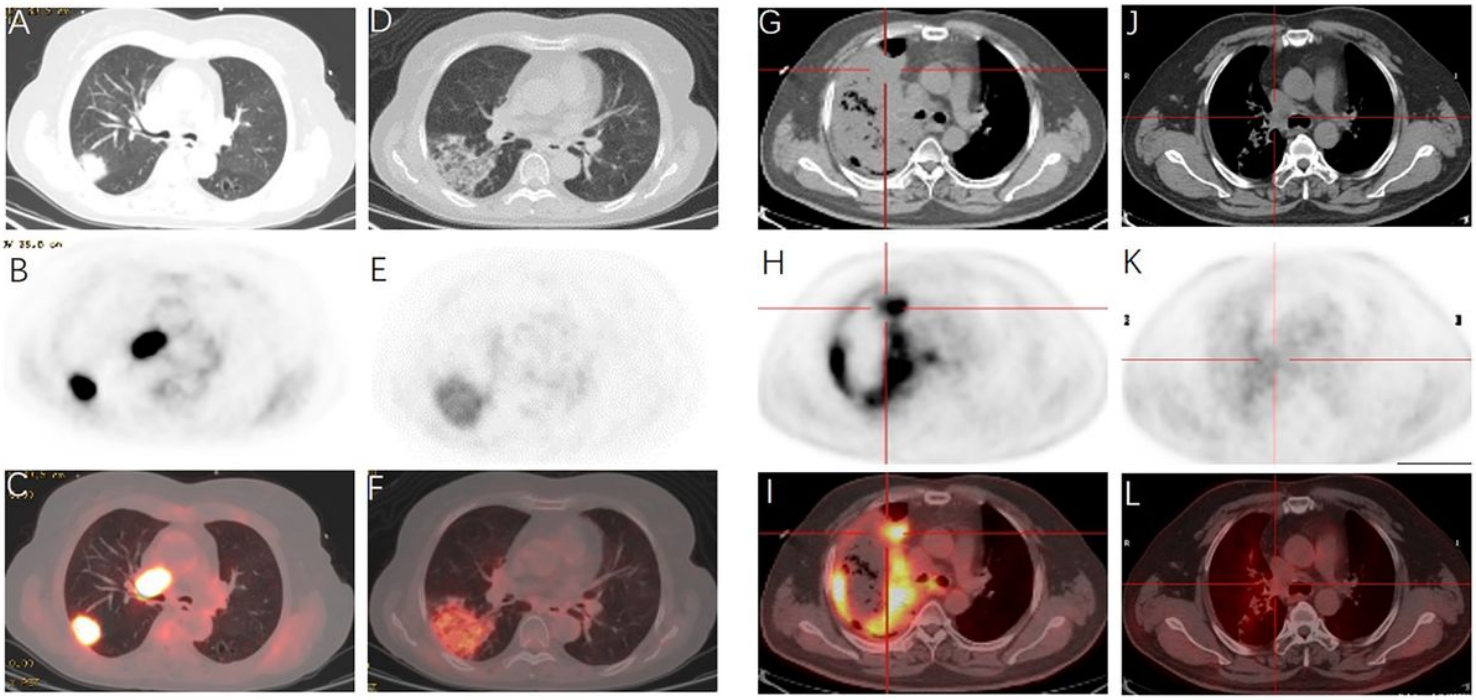

Figure 1

Left PET-CT images from one patient showing before (A, B and C) and after SBRT (D, E and F) respectively. Right PET-CT images from another patient showing before (G, H and I) and after SBRT (J, K and L) respectively.