Using max SUV from PET to Assess Tumor Responses after Lung SBRT for Different Prescriptions

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Purpose: To compare tumor responses after lung Stereotactic body radiotherapy (SBRT) using maximum Standardized Uptake Value (SUV) from 18F-fluorodeoxyglucose (FDG) Positron Emission Tomography (PET) for different SBRT prescriptions.

Materials & Methods: Tumor responses among different SBRT prescriptions were compared by examining 48 treatments that used 4 different SBRT prescriptions. All SBRT patients were treated on 21iX and Trilogy machines (Varian Medical Systems, Palo Alto, CA) using RapidArc®. This study used a simplified tumor response criteria: (1) Complete Response (CR) — post max SUV (SUV_{post}) after SBRT in the treated tumor region was almost the same as the SUVs in the surrounding regions; (2) Partial Response (PR) — SUV_{post} was smaller than previous max SUV (SUV_{pre}), but was greater than the SUVs in the surrounding regions; (3) No Response (NR) — SUV_{post} was the same as or greater than SUV_{pre}. Some SUV_{post} reported as mild or favorable responses were classified as CR/PR. Biologically equivalent doses (BED) calculated using α/β of 10Gy were analyzed with assessments of tumor responses for different prescriptions.

Why do we use max SUV from PET to assess tumor responses?

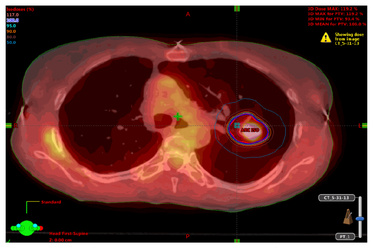

Fig.1. 11Gx5 SBRT Plan

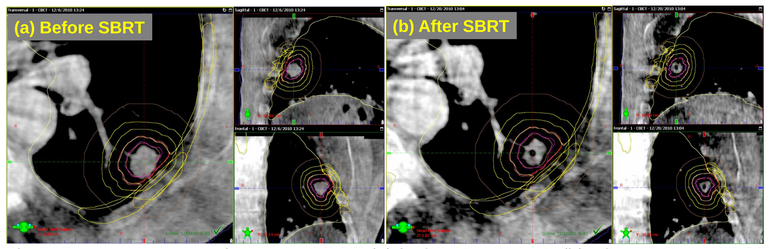

Fig.2. Tumor response shown on CBCT (a) before treatment; (b) after 12Gy×4 SBRT

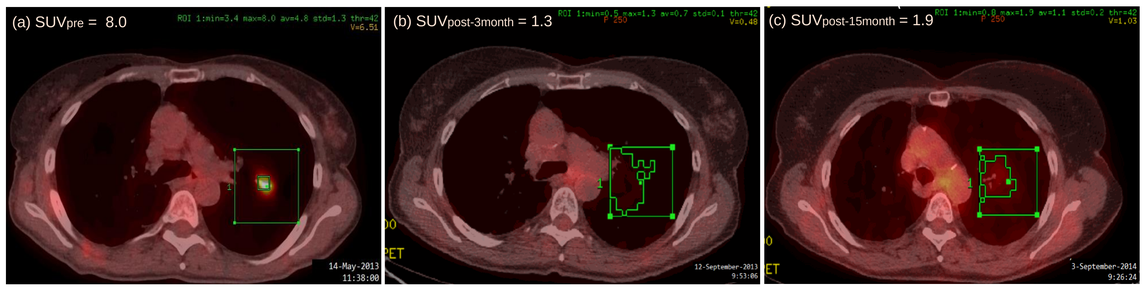

Fig.3. Tumor response shown on PET/CT: (a) SUV_{pre} = 8.0 (before treatment); (b) $SUV_{post\text{-}3month}$ = 1.3 (3 months after 11Gy×5 SBRT); (c) $SUV_{post\text{-}15month}$ = 1.9 (15 months after 11Gy×5 SBRT). Green boxes were ROI for SUV sampling.

CT is used as a mandatory follow-up to assess tumor local control, recurrence, and distant metastasis after radiotherapy. However, using CT, it may require more than 2 years to completely assess tumor responses, and so CT alone may be unable to accurately assess tumor response early enough to allow for some salvage treatment modalities. In Fig.2, there was obvious tumor shrinkage and density change after SBRT. However, for some patients, almost no change could be observed from CT one year after SBRT. PET measures biochemical changes using 18F-FDG rather than evaluating tumor size differences from images as CT does, and so PET is able to assess tumor response sooner than CT. PET/CT, a max SUV (a quantitative measure of 18F-FDG accumulation) read from PET and an ROI (a region covering the tumor) defined from CT, has become an important tool in assessing tumor response. In Fig.3, both max SUVs, in the treated tumor region, for 3 months and 15 months after SBRT were almost the same as the SUVs in the surrounding regions.

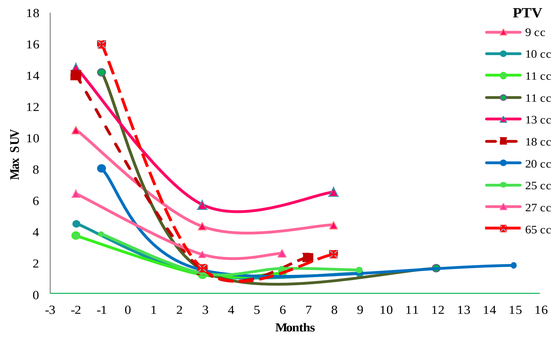

Fig. 4. Max SUV trends over time for 10 patients with more than two PET/CT scans after SBRT. SBRT completion was defined as month zero for each treatment. Max SUV values were connected with smoothed lines for each patient. PTVs were listed for the patients. the x-axis indicates the month before or after SBRT completion in which max SUVs were read. The 1st SUV_{post} was read at a median of 2.9 months after SBRT completion (range, 2.3 — 3.5 months) for this study.

We observed that all 1st SUV_{post} values were smaller than 2nd SUV_{post} values, a max SUV_{post} at or below 1.9 showed similar max SUVs in surrounding regions for patients treated with SBRT, $SUV_{post} \leq 1.9$ was classified as CR. 3-month post max SUV could efficiently assess local tumor responses after SBRT.

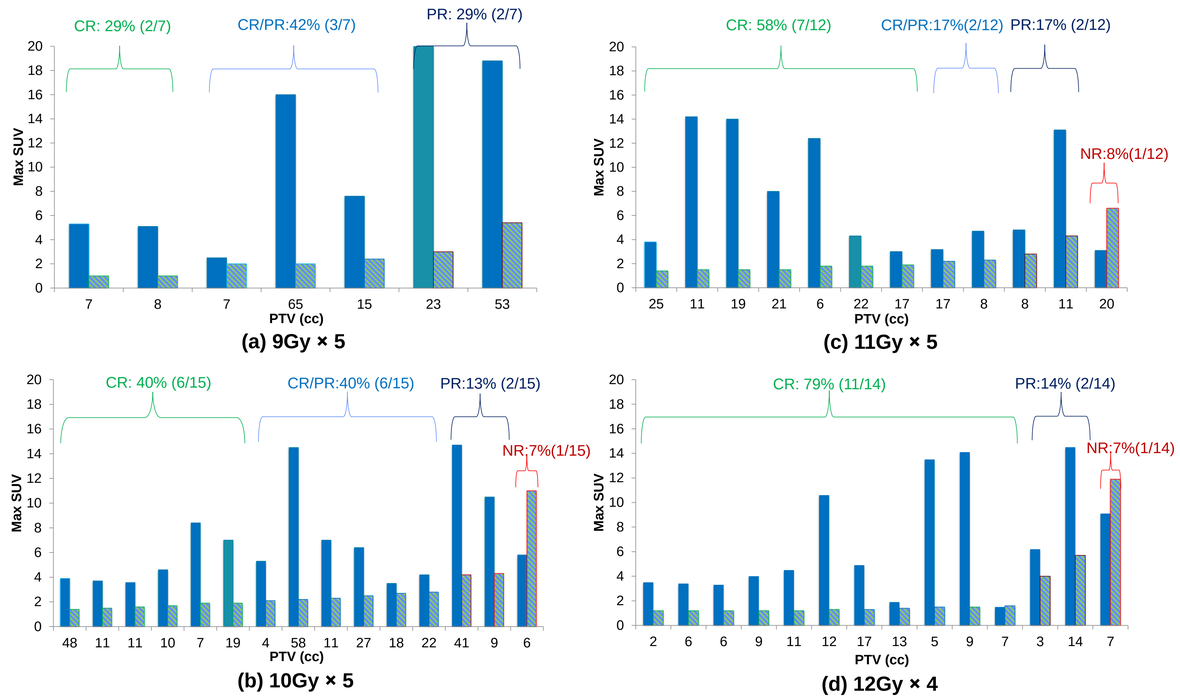

Fig.5. Max SUV for different prescriptions: Max SUV (y-axis) before SBRT(solid bars) and 3 months after SBRT(striped bars). x-axis shows PTV(cc) and is sorted by $SUV_{post\text{-}3month}$ for each prescription: (a) 9Gy×5; (b) 10Gy×5; (c) 11Gy×5; and (d) 12Gy×4.

Biologically equivalent dose (BED) has been introduced into optimal doses and fractionation schedules of SBRT:

$$BED = D \times (1 + d/(\alpha/\beta)) \quad (1)$$

where D: total dose; d: fractional dose; and α/β: ratio of the linear quadratic model when combined with clinical data on the steepness of the dose – response curve. BED_{10}, BED calculated using α/β of 10Gy in the linear quadratic model, is used as a predictor of local control in lung SBRT.

Table 1. Biologically equivalent dose and tumor response for different SBRT prescriptions

Prescription	PTV_{Ave} (cc)	BED_{10} (Gy)	CR (%)	CR/PR (%)	PR (%)	NR (%)
9Gy× 5	25.5	85.5	29	42	29	0
10Gy×5	21.1	100.0	40	40	13	7
11Gy×5	15.5	115.5	58	17	17	8
12Gy×4	6.8	105.6	79	0	14	7

Results: For four different SBRT prescriptions historically recommended by RTOG, our primary data (see Table 1) shown BED_{10} were 85.5Gy, 100.0Gy, 115.5Gy and 105.6Gy; and relevant complete response rate (CR) based on max $SUV_{post\text{-}3month}$ were 29%, 40%, 58% and 79% corresponding to 9Gy×5, 10Gy×5, 11Gy×5, and 12Gy×4, respectively. We observed that higher BED_{10} and lower tumor volume would achieve higher complete response (tumor control) rates. The highest complete response rate was observed for smallest tumor volume (PTV_{ave} = 6.8cc) with higher BED_{10} (105.6) of 12Gy×4 prescription. For 11Gy×5 prescription, its BED_{10} (115.5) was the highest in these 4 groups, but its complete response rate (58%) was lower than 79% of 12Gy×4 prescription. We observed the average tumor volume of 11Gy×5 group was more than double of the volume of 12Gy×4 group. It worth to note the current linear quadratic model to predict tumor control using BED [Eq. (1)] does not consider tumor volume and staging, etc. Recent studies also mentioned the escalation of BED to higher levels (>150Gy) may be required for patients with a tumor size > 3 cm.

Conclusion: We suggest 3-month post max SUV read from PET/CT should become standard tumor response assessment for lung SBRT. Although SBRT with prescriptions resulting in a BED_{10} > 100 experienced favorable tumor responses for normal non-small cell lung cancer (NSCLC), escalation of BED_{10} to higher levels, e.g. 150Gy, may be beneficial for patients with larger tumors undergoing lung SBRT.