Stereotactic Ablative Radiotherapy (SABR) of lung tumors: A pictorial review

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Disclosure

• Authors have no relevant financial relationships with the manufacturers of any commercial products and/or providers of commercial services

• We do not intend to discuss an unapproved use of a commercial product/device in this presentation
Teaching points

- Review cross sectional findings of post SABR pulmonary neoplasms
- Direct comparison of imaging findings with PET/CT findings
- Discuss pearls and pitfalls in accurately diagnosing and residual/recurrent tumors and mimics

Table of contents/outline

- General overview of stereotactic ablative radiotherapy (SABR)
- Describe the cross sectional and PET/CT features of recurrent/residual tumors and their mimics
- Identify the imaging and non-imaging features of each that may allow differentiation from others.
- Discuss the diagnostic pitfalls and management of the discussed entities.
Lung cancer

- Higher prevalence in white males and females
- 2 out of 3 patients older than 65
- Less than 2% younger than 45
- Average age 70
- Each year more people die of lung cancer than of colon, breast, and prostate cancers combined

- Leading cause of cancer mortality.
- 29% and 26% of all cancer deaths in men and women.
- Main cell types: Adenocarcinoma, Small cell, Large cell, and SCC
- Life time risk: 1 in 14 for male; 1 in 17 for female
- Risk factor: Smoking
Stereotactic Ablative Radiotherapy (SABR)

- also known as Stereotactic Body Radiotherapy (SBRT)
- Advocated for treatment for T1N0 or T2N0 non-small cell lung cancer
- Conveys high dose of radiation to a small focus in the body
- 90% local control rate
- Disease recurrence post-SABR occurs in the first 3 years post treatment
- 0% 30-day mortality after SABR in patients with severe COPD, versus 10% mortality after surgery

SABR: Inoperable stage I NSCLC

Computer optimized beam shaping & arc delivery
SABR for Inoperable stage I NSCLC

Inverse planned arc SABR
SABR versus older radiotherapy techniques

- Faster treatment course, 1-2 weeks versus 4-6 weeks
- 18 Gray per day versus 2 Gray per day
- Target dose 60 Gray
- More patient satisfaction and comfort
- Less cost
- Greater survival rate

Respiratory-gated arc SABR
Post SABR CHEST CT and PET/CT Findings

- Variable, but parenchymal changes generally visible in 2-3 months following radiation
- First manifestation: tumor shrinkage
- Most common: ground glass and consolidation
- Progression to contraction and fibrosis
- Initial increased FDG uptake, greater than lung background, with decreased tumor uptake, followed by peak diffuse FDG uptake in irradiated area, with gradual subsequent decrease in FDG uptake
## Imaging Features of Local Recurrence

<table>
<thead>
<tr>
<th>Suspicious Feature on CT</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enlarging opacity at primary site</td>
<td>92%</td>
<td>67%</td>
</tr>
<tr>
<td>Sequential enlargement</td>
<td>67%</td>
<td>100%</td>
</tr>
<tr>
<td>Enlargement after 12 months</td>
<td>100%</td>
<td>83%</td>
</tr>
<tr>
<td>Bulging margins</td>
<td>83%</td>
<td>83%</td>
</tr>
<tr>
<td>Linear margin disappearance</td>
<td>42%</td>
<td>100%</td>
</tr>
<tr>
<td>Loss of air bronchograms</td>
<td>67%</td>
<td>96%</td>
</tr>
<tr>
<td>Cranio-caudal growth of &gt;5mm and &gt;20%</td>
<td>92%</td>
<td>83%</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Suspicious Feature on PET-CT</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUV max &gt; 4.2</td>
<td>100%</td>
<td>96%</td>
</tr>
<tr>
<td>Focal uptake 1.5x greater than background</td>
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</tbody>
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Huang et al. Radiotherapy Oncology 2013
Takeda et al. Lung Cancer 2013
Post radiation evolution,
axial plane

Pre-treatment

2 months

6 months

9 months

12 months

16 months
Post radiation evolution, coronal plane

Pre: Pre-treatment  
2 months  
6 months

9 months  
12 months  
16 months
Baseline tumor was mildly avid (SUV max 1.7). Peak consolidation was at 5 months post SABR (SUV max 2.7). At 29 months the FDG-avidity has decreased to an SUV max of 2.0. On CT at 29 months the consolidation has contracted, consistent with fibrotic changes.
SABR: Side-effects and Complications

- Fatigue
- Chest wall pain
- Rib fracture
- Diffuse Radiation pneumonitis
- Esophagitis
- Local Recurrence reported in up to 10%
SABR complication: Rib Fractures

11 months

14 months
Complications:
Diffuse Radiation Pneumonitis

- Graded into 1-4 based on clinical severity
- Treated with steroids, oxygen, hospitalization
- Imaging Findings: Ground glass opacities and consolidations
- COPD protective against radiation pneumonitis
  - Odds ratio of 0.37 of RP for patients with severe COPD (GOLD 3 & 4) compared to patients without COPD [2]
- Increased risk for RP among those with:
  - Interstitial lung disease: severe or fatal RP in 26% [3]
  - Large tumors (> 80 cc)

Diffuse Post-Radiation Pneumonitis

Baseline

1 week

4 months

4 months
Local Recurrence: cranial caudal growth

Baseline

3 months

15 months

34 months

11 months

34 months
Local Recurrence Detected on CT and PET-CT

Mildly FDG-avid baseline tumor (SUV max 1.7). At 15 months, CT displays evidence of enlarging opacity while PET-CT shows a new hypermetabolic focus within the enlarging consolidation (SUV max 9.1). Subsequent biopsy revealed recurrent local disease.
False Negative CT for Recurrence

CT 14 months post SABR shows non-specific consolidation and volume loss, while PET-CT shows a new intensely FDG-avid focus within the consolidation (SUV max 8.5), consistent with subsequently biopsy-proven local recurrence.
Local Recurrence:
Positive on CT, Negative on PET-CT

Baseline tumor is non-FDG avid (SUV max 0.6). Follow-up PET-CTs at 9 and 17 months show no FDG-avidity within the consolidation. CT at 17 months shows enlarging opacity that on biopsy was proven to represent local recurrence.
PET/CT, CT or both?

- PET-CT has limited role in surveillance of tumors of baseline low FDG-avidity. Infection/inflammatory disease lowers specificity of FDG PET-CT.

- PET-CT is useful to identify nodal or distant metastases, which can be occult on CT.

- CT and PET-CT are complementary modalities and may maximize sensitivity in detection of post-SABR recurrence of NSCLC.

- Further studies are required to establish recommendations for CT and PET-CT to maximize early detection of recurrence.

- Novel techniques such as quantitative image analysis are currently being studied as potential alternatives.
Summary

- SABR/SBRT is an established therapy for early stage lung cancer in poor surgical candidates, particularly those with COPD.
- Likely will be increasingly used to treat lung cancer screening CT detected cancers.
- Post-radiation changes can be variable, but follow general trend of focal ground-glass/consolidation and progression to fibrosis.
- Local recurrence reported in up to 10%.
  - CT: increasing size after 12 months, loss of air bronchograms, increasing cranial-caudal dimension >20%.
  - PET-CT: Increasing SUVmax >4.2, Increasing focal SUVmax > 1.5x background.
- PET-CT can be very helpful in workup.
Selected references


Thank You!
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