Clinical Targets and Treatment Planning II
SABR for Lung Cancer
Clinical Targets: Lung

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Outline of Presentation

• Clinical background

• Target delineation

• Thoracic anatomy OARs relevant to lung SABR
  – Lung
  – Proximal bronchial tree
  – Esophagus
  – Spinal cord
  – Brachial plexus
  – Ribs and chest wall
  – Heart
  – Pericardium
  – Great vessels
Learning Objectives

- Appreciate various acceptable & unacceptable ways for target delineation.
- Recognize the need for consistency in OAR delineation that will result in more accurate toxicity measurements.
- Recognize that target delineation and OAR delineation/constraints are currently in an evolving state that will change as more data from recently closed protocols becomes available.
Survival in Lung Cancer

SABR Results:
• Local Control at 3 yrs: 85-98%
• Overall Survival at 3 years in medically inoperable: 55-60%
• Overall Survival at 3 years in medically operable: 75%

National Lung Screening Trial (NLST)  
NEJM 6/2011  

The NEW ENGLAND JOURNAL of MEDICINE  

ORIGINAL ARTICLE  

Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening  
The National Lung Screening Trial Research Team  

- > 50,000 patients  
- Identified lung cancer at an earlier stage  
- 20% lung cancer specific mortality benefit  
- 7% overall mortality benefit  

10/2011  
NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®)  
Lung Cancer Screening  
Version 1.2012  
NCCN.org  

1/2012  
Rescue Lung Rescue Life  
at Lahey Clinic  

12/2013  
U.S. Preventive Services Task Force Recommendation Statement
Number of patients with early stage lung cancer presenting for definitive thoracic SABR will be increasing.

- > 50,000 patients
- Identified lung cancer at earlier stage
- 20% lung cancer specific mortality benefit
- 7% overall mortality benefit
Simulation

• Immobilization:
  – Stereotactic body frame
  – Abdominal compression
  – Immobilization Bag (Vac-Lok)
    +/- wingboard
    • Full body
    • Thoracic

• CT scanning:
  – Free breathing
  – Breath-hold
  – 4DCT
    • ITV
    • Gated

• MD must participate
• Immobilization must address comfort and envelop patient on 3 sides
• Motion assessment and management
Target Delineation

- **GTV**
  - Free-breathing
  - Average

- **CTV**
  - RTOG currently assumes GTV=CTV

- **ITV**
  - #1 MIP
  - #2 Check/modify on all individual phases (e.g. movie mode)

- **PTV**
  - Expand ITV by 5mm if 4DCT
  - 3mm too small

ICRU-62:

GTV->CTV->ITV->PTV
MIP alone may miss
<table>
<thead>
<tr>
<th>Organ</th>
<th>Volume affected</th>
<th>Radiation type</th>
<th>Simultaneous or sequential</th>
<th>Dose CI (%)</th>
<th>Tumor response</th>
<th>Acute or chronic</th>
<th>Notes on chronic response</th>
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<tbody>
<tr>
<td>Right atrium, atrial appendage</td>
<td>Heart, right atrium</td>
<td>3D-CTRT</td>
<td>Simultaneous</td>
<td>10</td>
<td>High</td>
<td>No</td>
<td>Not applicable to SABR</td>
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<td>Simultaneous</td>
<td>20</td>
<td>Moderate</td>
<td>No</td>
<td>Not applicable to SABR</td>
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<tr>
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<td>3D-CTRT</td>
<td>Simultaneous</td>
<td>30</td>
<td>Low</td>
<td>No</td>
<td>Not applicable to SABR</td>
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<tr>
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<td>Whole organ</td>
<td>3D-CTRT</td>
<td>Simultaneous</td>
<td>25</td>
<td>Low</td>
<td>No</td>
<td>Not applicable to SABR</td>
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<td>Whole organ</td>
<td>3D-CTRT</td>
<td>Simultaneous</td>
<td>35</td>
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<td>3D-CTRT</td>
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<td>40</td>
<td>Very High</td>
<td>No</td>
<td>Not applicable to SABR</td>
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<tr>
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<td>3D-CTRT</td>
<td>Simultaneous</td>
<td>50</td>
<td>Low</td>
<td>No</td>
<td>Not applicable to SABR</td>
</tr>
</tbody>
</table>

**Table 2: QUANTEC Summary—Approximate Dose/Volume/Outcome Data for Several Organs Following Conventional Fractionation (Unless Otherwise Noted)** (Continued)
“[This table] summarizes tolerance doses from [two respected U.S. centers]. The doses are mostly unvalidated, and while most are based on toxicity observation and theory, there is a measure of educated guessing involved as well.”
Overview

Serious Complications Associated with Stereotactic Ablative Radiotherapy and Strategies to Mitigate the Risk

S.S. Lo *, A. Sahgal †, E.L. Chang ‡, N.A. Mayr §, B.S. Teh ¶, Z. Huang §§, T.E. Schechter ‡‡, M. Yao *, M. Machtay *, B.J. Slotman ††, R.D. Timmerman ‡‡

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Thoracic SABR Toxicities

- Radiation pneumonitis
- Bronchial necrosis/stenosis
- Brachial plexopathy
- Chest wall pain & rib fracture
- Dermatitis
- Esophageal fistula/stricture
- Cardiac
RTOG SABR Protocols

- **0236**: Phase II Trial of SBRT in Pts with Medically Inoperable Stage I/II NSCLC
  - closed to accrual and published JAMA 2010
- **0618**: Phase II Trial of SBRT in Pts with Operable Stage I/II NSCLC
  - closed to accrual and presented at ASCO 2013
- **0813**: Phase I/II Study of SBRT for Early Stage, Centrally Located, NSCLC in Medically Inoperable Patients
  - closed to accrual 2013
- **0915**: Randomized Phase II Study Comparing 34 Gy x 1 vs 12 Gy x 4 in Medically Inoperable Patients with Stage I Peripheral NSCLC
  - closed to accrual and presented ASTRO 2013
- **1021**: Randomized Phase III Study of Surgery vs SBRT Pts with Stage I NSCLC
  - closed after failing to accrue (10/420 pts)

- Target delineation
- Organs at risk
- Dose limits

All well-defined and remained stable throughout protocol progression
CONSIDERATION OF DOSE LIMITS FOR ORGANS AT RISK OF THORACIC RADIOThERAPY: ATLAS FOR LUNG, PROXIMAL BRONCHIAL TREE, ESOPHAGUS, SPINAL CORD, RIBS, AND BRACHIAL PLEXUS

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Suresh Senan, M.D.,‡ Laurie E. Gaspar, M.D.,§ Ritsuko U. Komaki, M.D.,∥
Coen W. Hurkmans, Ph.D.,‖ Robert Timmerman, M.D.,# Andrea Bezjak, M.D.,**
Jeffrey D. Bradley, M.D., †† Benjamin Movsas, M.D., †† Lon Marsh, C.M.D.,* Paul Okunieff, M.D., §§
Hak Choy, M.D., # and Walter J. Curran, Jr., M.D. ††

Atlases for Organs at Risk (OARs) in Thoracic Radiation Therapy

Feng-Ming (Spring) Kong MD PhD
Leslie Quint MD
Mitchell Machtay MD
Jeffrey Bradley MD
Lung

- Auto-contour air-inflated lung parenchyma
- Always review & edit
  - Include small sized vessels (<1 cm or vessels beyond the hilar region)
  - Include collapsed lung
  - Exclude fluid
  - Exclude Proximal Bronchial Tree
  - Exclude GTV
Proximal Bronchial Tree

- Use mediastinal windows and include all layers of bronchi.
- Include (1) inferior 2cm of distal trachea, (2) carina, (3) R&L mainstem, (4) R upper, intermedius, middle, lower lobe bronchi, (5) L upper, lingular, and lower lobe bronchi.
Proximal Bronchial Tree

- Use mediastinal windows and include all layers of bronchi
- Include (1) inferior 2cm of distal trachea, (2) carina, (3) R&L mainstem, (4) R upper, intermedius, middle, lower lobe bronchi, (5) L upper, lingular, and lower lobe bronchi
Esophagus

- RTOG SABR protocols: 10cm above and below PTV
- RTOG Atlas: True anatomy from cricoid cartilage until it ends at stomach
- Use mediastinal windows and include all layers
Spinal Cord

- Bony limits of spinal canal
  - RTOG SABR protocols: 10cm above and below PTV
  - RTOG Atlas: True anatomy from base of skull (or as high as available on scan) to L2
    - Cricoid cartilage – L2
- Spinal cord ends around L1-L2
- Brachial plexus involves C5-T1 nerves which fall between neural foramina at C4-C5 and T1-T2 interspaces.
DEVELOPMENT AND VALIDATION OF A STANDARDIZED METHOD FOR CONTOURING THE BRACHIAL PLEXUS: PRELIMINARY DOSIMETRIC ANALYSIS AMONG PATIENTS TREATED WITH IMRT FOR HEAD-AND-NECK CANCER

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doi:10.1016/j.ijrobp.2008.03.004
Brachial Plexus

Subclavian vessels as surrogate

- **RTOG SABR protocols**
  - Major trunks of the brachial plexus will be contoured using the subclavian and axillary vessels as a surrogate for identifying the location of the brachial plexus.
  - Neurovascular complex will be contoured starting proximally at the bifurcation of brachiocephalic trunk into the jugular/subclavian veins (or carotid/subclavian arteries) and following along the route of the subclavian vein to the axillary vein ending after the neurovascular structures cross the second rib.

- **RTOG Atlas**
  - Similar, but using high-quality CT scanning with intravenous contrast, it is possible to identify the actual roots and trunks of the brachial plexus directly without the need for a surrogate.

Possible to identify BP without surrogate
Brachial Plexus

Scalars and Prevertebral Muscles

- Jugular process of occipital bone
- Mastoid process
- Styloid process
- Longus capitis muscle
- Posterior tubercle of transverse process of axis (C2)
- Longus coli muscle
- Scalene muscles
  - Anterior
  - Middle
  - Posterior
- Phrenic nerve
- Scalenus anterior
- Internal jugular vein
- 1st rib
- Common carotid artery
- Posterior tubercle of transverse process of C7 vertebra

Comparison of Embryonic Limb Organization to the Plexus of the Brachial Plexus

- Cervical plexus
  - Contribution from C4
  - Contribution from T2

- Thoracic plexus
  - Contribution from T6, T7

- Occipital branch
  - Cervical branch
  - Thoracic branch

- Brachial plexus
  - Musculocutaneous nerve
  - Median nerve
  - Ulnar nerve
  - Thoracodorsal nerve
  - Intercostal nerve

- Axillary nerve
  - Musculocutaneous nerve
  - Median nerve
  - Ulnar nerve
  - Thoracodorsal nerve
  - Intercostal nerve

- Radial nerve
  - Musculocutaneous nerve
  - Median nerve
  - Ulnar nerve
  - Thoracodorsal nerve
  - Intercostal nerve

- Thoracodorsal nerve
  - Musculocutaneous nerve
  - Median nerve
  - Ulnar nerve
  - Thoracodorsal nerve
  - Intercostal nerve

- Intercostal nerve
Brachial Plexus

- T1 nerve root passes under 1st rib before merging with rest of BP between clavicle and 1st rib.
  - T1 inadvertently not contoured often

Brachial Plexus
Ribs & Chest Wall

Ribs and chest wall limits may be exceeded for an otherwise excellent plan.

• RTOG SABR protocols
  – Ribs within 5 cm of the PTV should be contoured by outlining the bone and marrow.
  – Do not include the intercostal space as part of the ribs

• RTOG Atlas
  – Ribs and chest wall can be autosegmented from the lung with a 2 cm expansion.
  – Include the intercostal muscles.
  – Ribs within 3 cm of the PTV.
Heart, Pericardium & Great Vessels

• RTOG SABR protocols
  – Heart & Pericardium combined.
    • Start under the aorta and extend inferiorly to the apex.
  – Great Vessels = Aorta and vena cava, not the pulmonary artery and vein

• RTOG Atlas
  – Heart and Pericardium are separate structures
  – Heart is further divided into separate chambers
  – Great Vessels = Aorta, vena cava, pulmonary artery and vein.
Development and Validation of a Heart Atlas to Study Cardiac Exposure to Radiation Following Treatment for Breast Cancer

Mary Feng, M.D.,* Jean M. Moran, Ph.D.,* Todd Koelling, M.D.,† Aamer Chughtai, M.D.,‡ June L. Chan, M.D.,* Laura Freedman, M.D.,* James A. Hayman, M.D.,* Reshma Jaggi, M.D., D. Phil.,* Shruti Jolly, M.D.,* Janice Larouere, M.D.,* Julie Soriano, M.D.,* Robin Marsh, C.M.D.,* and Lori J. Pierce, M.D.*

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Heart
Summary

1. Lung SABR is on the rise.
2. Normal tissue dose tolerances in lung SABR are still evolving and only a limited experience exists from which to draw recommendations.
   - RTOG & TG-101
3. High level consistency in OAR delineation is necessary to develop more accurate toxicity measurement.
   - RTOG protocols & RTOG Lung Atlas
References

RTOG Lung SABR protocols: 0236, 0618, 0813, 0915, 1021

RTOG OAR Atlas for Thoracic RT

