Spectrum of applications of SBRT

- Intensified treatment to a primary cancer
  - Stage I lung cancer
  - Primary HCC
  - Pancreas cancer
  - Prostate cancer
- Palliation/control for challenging sites of recurrence
  - Spinal
  - Retroperitoneal
  - Previously irradiated volumes
- Adjuvant systemic cytoreductive therapy
  - “Radical” treatment for isolated liver, lung, spine, and other oligometastases

SBRT Planning Case Studies

- iTreat™
  - Customized educational software app
  - Case-based instruction
    - lung-focused with connection to other sites where appropriate to other sites
- Public Service Announcement
- Plus some questions along the way...

CPT code semantics

- SBRT term can be used for fractionated brain tumor SRS for the MD pro fee
  - But the delivery code is SRS
- SRS is the term used for primary OR BOOST treatment to base of skull region tumors
- SBRT describes an entire course of treatment, not a boost phase of treatment
### The amalgamated case

- 70 y/o former opera house worker
  - heavy smoker, medically inoperable
  - his girlfriend is frightened of him
  - a bit of a stiff overall

- T1N0M0 NSCLC

### Challenge question: what are the potential problems with this plan?

<table>
<thead>
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Breathing motion management for planning & delivery

- Forced shallow breathing techniques
  - Abdominal compression
- Breath-Hold (BH) CT-Scans
  - Can be device-assisted
- Free Breathing CT-Scan
  - Slow: creates ITV
  - Fast: obtain end-inspiration & end-expiration
- Respiratory Gated CT and 4D-CTs
  - Popular
- Modeled breathing motion (tracking)
  - Specific commercial system

Quantitative analysis of abdominal pressure relative to breathing motion

Note: high compression force approx 90N or approx 22 pounds, reduced diaphragm sup-inf motion from approx 15mm to 8 mm on average

Lung v liver SBRT: 2 issues

- Pressure belt placement
- MIP v MinIP to generate ITV

4D CT simulation
note: belt higher than for liver, where we don’t want to deform the target organ
**MINIP vs MIP: a few comments**

Notice one obvious difference between MINIP and MIP is the volume of liver projected, since the lower density adjacent tissues that move with respiration provide the minimum HU voxels.

MIP usually appropriate for lung ITV
MINIP often helpful for liver ITV, but be careful with lesion near the dome

**Possible problems**

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According to Heinzerling et al, the application of approximately 90 N (22 pounds) of abdominal compression force reduces the average total breathing-related motion of liver or lower lobe lung tumors (rounded to nearest mm) from 14 mm to

- 3% 1. 12mm
- 90% 2. 7mm
- 6% 3. 3mm
- 3% 4. 1mm
According to Heinzerling et al, the application of approximately 90 N (22 pounds) of abdominal compression force reduces the average total breathing-related motion of liver or lower lobe lung tumors (rounded to nearest mm) from 14 mm to:

1. 12 mm
2. 7 mm
3. 3 mm
4. 1 mm

Ref: Heinzerling J, et al. Four Dimensional Computed Tomography Scan Analysis of Tumor and Organ Motion at Varying Levels of Abdominal Compression During Stereotactic Treatment of Lung and Liver. Int J Rad Oncol Biol Phys 2008; 70(5): 1571-1578

THE POINT: YOU CAN GET SUP-INF MOTION TO LESS THAN 1 CM IN MOST BUT NOT ALL CASES. AND THERE WILL ALWAYS BE SOME RESIDUAL.

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Anything else?

Be mindful of intrafraction motion

Purdie et al, IJROBP 2007
Intrafraction motion, lung sbrt

Verbakel et al, Radiother Oncol 2009
VMAT for rapid delivery of SBRT

N = 3
Good dosimetry
Beam on time reduced approximately 50% using VMAT delivery

Note: rotational IMRT delivery can be faster, but another caveat applies (to be discussed later)
7 non-coplanar beams
PTV DVH, 0mm v 1cm margin

Hotter hotspot in
tumor with 0mm
BEV margin v larger
margin

Steeper
dose falloff in
lung

Lower NTCP

Note: consider the NTCP estimates
proof of principle, not absolute values

Other lung SBRT planning
issues

• Anatomic location
• Chest wall dose
• Ipsilateral mean lung dose

Cautionary note:
Possible problems near the proximal airways
RTOG dose escalation study underway

Freedom from grade 3-5 toxicity
Tennessen et al., JCO, October, 2006
Chest Wall Pain and/or Rib Fracture

- Dunlap et al, IJROBP 2009
  - 60 peripheral lung lesions treated with SBRT
  - 17 CWP, 5 fractures at a median of 7 months
  - Correlated to volume receiving ≥30 Gy (V30)
    - Steep increase for V30>30cc

Radiation Pneumonitis

Ricardi et al, Acat Oncol 2009

- 63 patients
  - 9/63 Grade 2+ RP
  - Correlated with ipsilateral Mean Lung Dose
    - corrected to 2Gy equivalent—approx same as absolute for MLD 8-10 Gy
    - No toxicity for MLD≤ 12 Gy

Yamashita et al, Radiation Oncology, 2007

- 25 lung patients
  - 18 primary, 7 metastatic
- SBRT dose:
  - 48 Gy/4 fractions
  - Prescribed to isocenter
- 7/28 Grade 2 or higher RP including 3 Grade 5 toxicity
- Essential problem:
  - Conformity Index (CI)
    - Defined as PTVmin dose volume/PTV
    - Correlated with RP (p=0.04)
    - Mean CI approx 2
    - Very high!!!
  - “We set the leaves at 5 mm outside the PTV...to make the dose distribution within the PTV more homogeneous. This may be the reason why we got so unacceptably high CI. We might have had to set the leaves at the margin of the PTV.... There must be something wrong with...the way targets are irradiated.”

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- Doesn’t allow steep dose gradient
- Too much lung
From U Colorado Phase II liver SBRT trial

Photo taken 8 mos after SBRT
At last followup 17 post-SBRT, lesion was controlled.
Necrosis was slowly healing.

Suggestion: no discontinuous hotspot that you wouldn’t want to go to spinal cord, ie 18 Gy/3txns

7 beam, non-IMRT, 0mm margin quick first pass plan already better

CK 60 Gy hotspot, could be better F50 approx 4
Compare 56 Gy lukewarm spot

Small 15 Gy volume No discontinuous 18 Gy

For a 3 fraction lung SBRT regimen, the following normal tissue DVH metric has been associated with increased risk of pneumonitis:

<table>
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<tr>
<td>Mean ipsilateral lung dose &gt; 12 Gy</td>
<td>87%</td>
</tr>
<tr>
<td>Total Lung V20 &gt; 25%</td>
<td>15%</td>
</tr>
<tr>
<td>Total Lung V15 &gt; 35%</td>
<td>6%</td>
</tr>
<tr>
<td>Total Lung V5 &gt; 50</td>
<td>4%</td>
</tr>
<tr>
<td>Maximum proximal bronchial tree dose &gt; 40 Gy</td>
<td>8%</td>
</tr>
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Ref:
Reasonable sources of guidance for SBRT normal tissue dose constraints

• Selected RTOG SBRT studies
• QUANTEC papers—very limited SBRT, mostly conventional
  • Liver
    • Pan et al, IJROBP 76(3) Suppl: S94–S100, 2010
  • Kidney
    • Dawson et al, IJROBP 76(3) Suppl: S94–S100, 2010
  • Stomach and small bowel
    • Kavanagh et al, IJROBP 76(3) Suppl: S94–S100, 2010
  • Mostly unvalidated but well considered estimates for 1, 3, and 5 fractions

Public Service Announcement

• Safety and quality in the performance of high-tech radiation therapy services is of the highest priority
• ASTRO has been creating a series of “White Papers” and other documents laying out details
  – Eg, SBRT White Paper
  • Special thanks: Tim Solberg

“Towards Safer Radiotherapy”

• Published 4/2008
• Contains analysis of UK data
• Estimate a rate of 3/100,000 risk of a course of treatment involving ≥10Gy overdose

https://www.rcr.ac.uk/docs/oncology/pdf/Towards_saferRT_final.pdf
“Towards Safer Radiotherapy”, continued

- Error definition/grading scale provided
- Checklists encouraged
- For the UK a national reporting system established

Ongoing data reporting/analysis

Most “near misses” occur at the treatment unit

Additional sources of guidelines for SBRT performance


Data recorded from the UK’s “Towards Safer Radiotherapy” project indicates that the most common source of radiation treatment error “near misses” is the following:

<table>
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<tr>
<td>81%</td>
<td>Procedures at the point of RT delivery</td>
</tr>
<tr>
<td>11%</td>
<td>Planning software programming errors</td>
</tr>
<tr>
<td>2%</td>
<td>New equipment commission</td>
</tr>
<tr>
<td>2%</td>
<td>Inaccurate patient-specific QA verification</td>
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<tr>
<td>5%</td>
<td>Scheduled linac QA checks</td>
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www.rcr.ac.uk/docs/oncology/pdf/Towards_saferRT_final.pdf