

WE-E-BRB – Motion Management for Pencil Beam Scanning Proton Therapy August 3, 2016







## Some tumors move a lot...





# Proton close and motion If the second s

- Organ motion creates changes in beam paths
   Interplay effect of spot scapping
- Interplay effect of spot scanning vs. respiratory motion → underand Over-doses

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# Not all tumors move that much...

20 lung cancer patients (21 tumors)
2-mm gold marker under fluoroscopic imaging



## Not all tumors move that much...

 191 lung cancer patients (94 early stage, 97 locally advanced) NSCLC



Locally advanced < early stage Superior/Inferior has the largest motion





## How to quantify the motion?

- Along the beam direction:
  - Motion in this direction has little dosimetric effect
  - WET changes selecting gantry angles with smallest ∆WET
- Perpendicular to the proton beam direction:
  - In the axial plane depending on gantry angle
  - Superior/inferior direction independent gantry angle

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## Tumor motion analysis

- Using ray tracing method to determine WET changes between T0 & T50 along the beam direction
- Deformation vector between T0 & T50 for motion analysis 3 components:
   Parallel to the proton beam
   Perpendicular to the proton beam in the axial plane



## Tumor motion analysis - Example Adenocarcinoma of the left lower lobe lung



## Tumor motion analysis - Example

Adenocarcinoma of the esophageal



## How to dosimetrically assess the motion interplay effect?

- 4D dose (4DD)- equally weighted average dose among the respiratory phases of 4DCT.
  4D dynamic dose (4DDD)- estimation of the delivered dose under the influence of the interplay effect
- 4DDD converges to 4DD as fraction increases -
- interplay effect will be averaged out •  $\Delta = 1FX4DDD - 1FX4DD \rightarrow Interplay Effect$





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Optimized Scanning	Sequence
Part form	et al, bRogs, 20.5











## 4D Robust Optimization





## **Breath hold**

- 15 patients with peripheral lung tumors previously treated with stereotactic radiation therapy
  Potential cick feat
- Potential risk factors for reduced coverage are:

### External surrogate

- Internal surrogate
- Fiducials
  Tumor or diaphragm
- In-room volumetric imaging
   CBCT
   CT on-rail

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## **Phase Controlled Rescanning**





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- Respiratory motion remains a challenge for scanning beam proton therapy:
  - · Practical strategies have been developed to selectively treat
  - The interplay effect is not as large as we use to think Rescanning will reduce the interplay effect
  - Fractioned treatment provides effective rescanning.
  - 4D robust optimization would be useful technique.
  - Breath hold, gating or combination would be further help for patients with larger motion.

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## **Options for Treating Moving Targets**

- Margin based approach:
  is needed but may not be sufficient
- Repainting (rescanning) :
   divide dose delivery to multiple times to average the interplay effect
- Breath-hold and gating:
   irradiation in a pre-defined motion window (e.g., end exhale)
- Tracking:
  - compensate tumor motion by 3D adaptation of the proton beam Knopf et al. Med Phys 2010



## Not all tumors move that much... Tumor motion was associated with diaphragm

- Tumor motion was associated with diaphragm motion, the SI tumor location, size of the GTV, and disease T stage.
- 152 lung cancer patients stage III or IV NSCLC
   Tumors that moved > 0.5 cm;
- Superior-inferior: 39%
   Lateral: 2%
   Anterior-posterior: 5%
   For 95% of the tumors, the magnitude of motion
   was
   Superior-inferior: < 1.3 cm
   Lateral: < 0.4 cm
   Anterior-posterior: < 0.6 cm
   Only 11% of tumors moving > 1.0 cm.



