Image Guided Radiation Therapy
– Edward Experience

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Outline

- PET/CT Simulation
- Manage Respiratory Motion – 4DCT Simulation
- On Board Imaging
Challenges in Radiation Therapy

- Identifying the tumor
- Defining the tumor and target
- Hitting the target
- Knowing the tumor response to radiation

Imaging and image registration is the key for addressing these challenges
Imaging Techniques are Rarely Used “Solo”

- CT
- MR
- PET
- Ultrasound
- PET/CT Simulation
- 4DCT Simulation
- On Board Imaging
PET for Radiation Therapy Planning
Why PET/CT Simulation?

- Distribution of activity is imaged
  - Physiology, function, biology
- Complementary to (~ anatomic) CT and MR
- Increased sensitivity compared to CT alone
- PET and CT in the same treatment position
- Accurate PET/CT fusion
PET/CT Simulation
PET can Decrease Target Volume
PET can Decrease Target Volume
PET can Increase Target Volume
PET can Increase Target Volume
PET can Increase Target Volume
Are they Moving?
More Challenges in Radiation Therapy

- Identifying the tumor
- Defining the moving tumor and target
- Hitting the moving target
- Knowing the tumor response to radiation
Types of Motion

- Intra-fraction
  - Within each fraction (example: lung)

- Inter-fraction
  - Between fractions (example: prostate)

- Combined with deformation
  - Example: pancreas
How to Monitor Breathing?

- Chest / abdomen height
  - Varian RPM System
- Belt based
  - Anzi Medical System (pressure based belt)
  - Philips (pneumatic belt)
- Metric spirometry
Varian RPM
4DCT Image Sorting

End-inspiration

End-expiration

Full respiratory cycle
4 sec

CT Image Sorting Program

Mid-exhale  End-exhale  Mid-inhale  End-inhale
Manage Respiratory Motion

4D CT

Tumor moves > 7mm?
- Yes
  - Regular breathing pattern?
    - Yes: Gating
    - No: Contour ITV
      - Use Average study set
- No: Use helical CT
ITV on Ave Study Set for Planning
ICRU 62 Target Volume Delineation

- GTV – Gross Tumor Volume
- CTV – Clinical Target Volume
- PTV – Planning Target Volume
ICRU 62 Target Volume Delineation

\[ \text{PTV} = \text{CTV} + \text{IM} + \text{SM} \]

- **IM** - Internal Margin, due to physiologic variations
- **SM** - Setup Margin, due to technical factors
ICRU 62 Definition

- OAR – Organ at Risk
- PRV – Planning Organ at Risk Volume
  - Margin added to OARs
ITV $\rightarrow$ Customized Target Volume

- GTV from Helical CT
- Treatment Field from Helical CT
- ITV
- Treatment Field from ITV
IGRT can Reduce Internal Margin, Setup Margin, and Margin to OAR
Reduce Treatment Margin

3D Conformal → IMRT → IGRT

Volume Treated

- Bladder
- Prostate
- Rectum
On Board Imager – Varian Trilogy
Image Matching

- 2D-2D matching of OBI images to DRRs
  - Anatomy matching
  - Implanted fiducials
- 3D-3D cone beam CT image match to treatment planning CT images
  - Anatomy matching
  - Structure set alignment of GTV, CTV, PTV, or contoured structures to acquired image
2D-2D Image Match

- Orthogonal pair of images
  - AP and Lateral – Brain, H&N
  - Orthogonal Oblique's - Pelvis
Brain: 2D-2D Anatomy Match
Brain: 2D-2D Anatomy Match
Pelvis: 2D-2D Anatomy Match
Spine: 2D-2D Anatomy Match
Prostate with Implanted Markers

CT

MRI
Prostate Implanted Marker Match
Prostate Implanted Marker Match
Lung CBCT – before matching
Lung CBCT – matched images
H&N CBCT 3D-3D Match
CBCT to Evaluate Tumor Response
CBCT to Evaluate Tumor Response
Average Shifts for Prostate

![Bar graph showing average shifts for prostate patients.](image)
Average Shifts for All Prostate Patients
Average Shifts for GBM
Average Shifts for All GBM Patients

- **Lat**
- **Lng**
- **Vert**
- **Vector**

Graph showing the average shifts in mm for different directions.
Average Shifts for H&N
Average Shifts for All H&N Patients

- **Vecotr**
- **Vert**
- **Lng**
- **Lat**

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# Average Shifts + 2 X Standard Deviation

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<td>Pancreas</td>
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## IGRT Action Levels
- Require Physician/Physics Review

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<th>Tumor Type</th>
<th>Action Level</th>
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<td>Prostate (Fiducials or Clips)</td>
<td>7 mm</td>
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<tr>
<td>GBM</td>
<td>5 mm</td>
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<td>H&amp;N</td>
<td>4 mm</td>
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<td>Other (Lung, Pancreas, etc)</td>
<td>10 mm</td>
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Quality Assurance

- Daily QA
  - Couch shifts with KV images
- Monthly QA
  - KV image – isocenter alignment
- Annual
  - CBCT – isocenter alignment
Daily QA

- Couch Shift Accuracy with KV Imaging
Monthly QA

- KV Image -
  Isocenter Alignment
KV Image – Isocenter Alignment
CT resolution and quality of DRR’s are limiting factors

Fiducial artifacts on CT images

Artifacts on CBCT due to organ motion

Treatment couch cannot tilt and spin
Conclusion

- PET/CT and 4DCT Simulations help us to
  - Delineate target volume and critical structure more accurately
  - Customize, often decrease, internal margin
- On Board Imaging gives us valuable tool to
  - Reduce setup error
  - Track inter-fractional target / organ motion
  - Reduce internal & setup margins
  - Track tumor response – Adaptive Therapy
Adaptive Radiation Therapy, or a Black Hole?
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