Daily Localization Using KV/CBCT

Fang-Fang Yin, Sua Yoo,
Duke University Medical Center, Durham, NC
Douglas Moseley, Michael Sharpe, Jeffrey H. Siewertsen
Princess Margaret Hospital, Toronto, ON
And Ontario Cancer Institute, Toronto, ON

Objectives

• Understand the latest commercially available technologies for in-room KV radiography, fluoroscopy, and cone-beam CT and their basic imaging principles
• Understand the basic clinical imaging applications for daily localization
• Understand the basic system limitations and QA components of a comprehensive QA program

Acknowledgements

• Invitation from the program committee
• Members of Radiation Oncology Department at Duke University Medical Center
• Duke University Medical Center has a master research agreement with Varian Medical Systems

Outlines of the Talk

• Introduction
• Imaging Systems and Methods
• Clinical Applications
• Image Quality (Dr. Siewertsen)
• Quality Assurance (Dr. Moseley)
Why In-Room – Prostate IMRT Case

Why In-Room: H&N Case

Why In-Room: Improving Precision and Accuracy

On-Board kV X-ray Imaging

- Room-Mounted System
- Gantry-Mounted System
- Mobile Systems

Accurate but not precise: IGRT
Precise but not accurate: IMRT
Precise and accurate: IGRT+IMRT

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Room-Mounted X-Ray Systems

- CyberKnife® imaging system
- Novalis® imaging system

Gantry-Mounted X-Ray Systems

- Elekta Synergy® system
- Varian Trilogy™ system

“Mobile” Systems

- Varian ExaCT™ at MDACC
- Siemens C-arm system

Duke On-Board Imager (OBI)

- KV source (KVS)
- KV detector (KVD)
- Portal imager (EPID, MVD)
- Clinac
- OBI
- 4DITC
- RPM
Radiographic Imaging Options

- Orthogonal radiograph
- Cone-Beam CT (CBCT)
- DTS - Digital Tomosynthesis

Radiographic Imaging Techniques

- 2-D radiographic imaging
- 2-D fluoroscopic imaging
- 3-D cone-beam imaging
- Limited scan angle 3-D digital tomosynthesis
- Respiratory-gated imaging

Clinical Applications

- Correction Strategies
  - Off-line Correction
  - On-line Correction

- Image Fusion
  - Manual
  - Automatic

2-D Radiographic Imaging

Good for auto fusion
Limited Angle DTS Imaging

0°  DRR  MV rad  kV rad

44°  RDTs  DTS

360°  CT  CBCT

Auto and manual fusion

Off-Line Portal Verification

Reference images

Compare → Next tx → Patient setup → Treatment → On-board images

What Will Off-Line Verification Do for Precision and Accuracy?

Systematic error
Random error
Accurate but not precise!!!!

On-Line Portal Verification

Patient setup → Reference images

On-board images → Correction?

Feedback → Treatment → Shift couch

On-board images

On-board images
What Will On-Line Verification Do for Precision and Accuracy?

Random error  Systematic error  Systematic & Random error  
Both Accurate and Precise!!!

Imaging for Respiratory-Gated Treatment

- Anatomical imaging
  - Breath-hold
  - Gated treatment
  - Real-time portal verification

- Dosimetric imaging
  - Intensity map

4-D Fluoroscopic Imaging

Markers  Gated Treatment

Breath-Hold Treatment Localization

DRR (breath-hold)  kV (free-breathing)  kV (breath-hold)
Breath-Hold CBCT

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Sim CT
CBCT Free-breathing
CBCT Breath hold

Breath-Hold Digital Tomosynthesis

Liver - Effect of Breath-Hold

Breath Real-Time Portal Verification

20 portal images in cine mode with < 1 s interval
**Planning CT with target contours**

**Free-Breath ITV Verification with CBCT**

**Total Treatment Time for IGRT**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient setup in the room</td>
<td>2 – 5 min</td>
</tr>
<tr>
<td>OBI kV/kV or MV/kV imaging</td>
<td>~ 1 min</td>
</tr>
<tr>
<td>2D/2D matching analysis</td>
<td>2 – 5 min</td>
</tr>
<tr>
<td>CBCT imaging</td>
<td>3 min</td>
</tr>
<tr>
<td>3D/3D matching analysis</td>
<td>2 – 5 min</td>
</tr>
<tr>
<td>Re-positioning</td>
<td>~ 1 min</td>
</tr>
<tr>
<td>Treatment delivery</td>
<td>10 – 15 min</td>
</tr>
<tr>
<td>Total treatment time for IGRT with CBCT</td>
<td>20 – 35 min</td>
</tr>
<tr>
<td>Total treatment time for IGRT without CBCT</td>
<td>15 – 25 min</td>
</tr>
</tbody>
</table>

**Hardware Requirements**

**Planning image data:**
- CT images: 0.514 MB/image
- MR images: 0.188 MB/image
- PET images: 0.034 MB/image

**Localization/verification image data:**
- kV image: 1.54 MB (1024x768x2)
- MV image: 0.386 MB (512x384x2)
- DRR image: 0.514 MB (512x512x2)
- CBCT images: 28 MB (55 x 0.512 MB)

**Typical CT-based plan size:** 50-200 MB
**Typical IGRT patient fold size:** 600MB-2GB

**Information Integration**

- Simulation
- Consultation
- Treatment
- Planning
- Follow-up

- Computation (Seconds, minutes?)
- Speed (Seconds?)
- Accessibility (Anywhere?)
- Quality assurance (Pre-, on-line? after?)
**Question 1**

Which of the following imaging systems is not used for real-time on-board imaging in the treatment room for patient positioning and target localization?

- A. The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room
- B. The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager
- C. The orthogonal kV x-ray imaging system with dual detectors/tubes, fixed to the treatment room
- D. The ultrasound imaging with an optical localization device
- E. The slice-by-slice tomographic imaging device with MV beams

**Question 2**

Which of the following imaging systems can be used to generate on-board cone-beam CT images in the treatment room for patient positioning and target localization?

- A. The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room
- B. The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager
- C. The orthogonal kV x-ray imaging system with dual detectors/tubes
- D. The CT-on-the-Rail device in the treatment
- E. The slice-by-slice tomographic imaging device with MV beams
**Question 2**
Which of the following imaging systems can be used to generate on-board cone-beam CT images in the treatment room for patient positioning and target localization?

- **A.** The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room (12%)
- **B.** The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager (67%)
- **C.** The orthogonal kV x-ray imaging system with dual detectors/tubes (7%)
- **D.** The CT-on-the-Rail device in the treatment (7%)
- **E.** The slice-by-slice tomographic treatment unit

**Question 3**
The time needed for acquiring projections around 360-degree gantry rotation to reconstruct on-board cone-beam CT data is about one minute. The reason is:

- **A.** The manufacturers are not able to rotate the gantry faster than this speed (5%)
- **B.** The engineering limitation prohibits any speed faster than this speed (3%)
- **C.** The IEC recommends a speed limitation for the treatment gantry rotation (78%)
- **D.** Both therapists and patients like this speed (1%)
- **E.** The limitation of data acquisition of the detector signals (13%)

Continued by Dr. Jeffrey H. Siewerdsen