MV Cone Beam CT Imaging for daily localization: (part II)

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Helen Diller Family UCSF Comprehensive Cancer Center, AAPM CE-Therapy Series (SAM), July 29th, 2008

Disclaimer

Part of the work performed on MVCBCT at UCSF is supported by Siemens OCS.
Course Objectives
MV Cone Beam CT Imaging for daily localization: (part II)

1- Commissioning
   (physics of, image quality, dose, registration process, acquisition mode, etc),
2- Clinical integration,
3- QA, stability over time, downtime, etc.
4- Complement standard clinical applications
5- Introduce novel clinical applications
6- Present technology evolution and future directions

1- Commissioning,
   (physics of, image quality, dose, registration process, acquisition mode, etc),
2- Clinical integration,
3- QA, stability over time, downtime, etc.
4- **Standard Clinical applications,**
   - Daily prostate alignment
   - Alignment and target delineation in presence of metallic objects
     - Hip Prosthesis
     - Surgical clips
     - Brachytherapy
     - Spinal lesions with supporting structures
Why MVCBCT for pelvic patients?

- Faster, objective and less dose than EPID + markers
  - 3-4 minutes
  - 3 cGy

- Provides additional 3D information
  - Volumetric info: Rectum, bladder, etc.
  - Prostate contours -> Dose recalculation
Alignment and target delineation in presence of metallic objects

- Imaging in presence of Hip Prostheses
  - Target delineation
  - Electron density
  - Marker visualization

- Prostatectomy patients
  - Surgical clips vs markers

- HDR Brachytherapy
  - Target delineation
  - Non-compatible CT applicators

Spinal cord delineation with MVCBCT registered to CT for planning purpose, for a patient with a metallic supporting structure
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   acquisition mode, etc),
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4- Standard Clinical applications,
5- Novel clinical applications
   - Concurrent treatment of prostate and pelvic lymph nodes with IMRT+IGRT
   - Breast daily alignment with contra-lateral breast dose sparing
   - Digital Tomosynthesis

Concurrent treatment of prostate and pelvic lymph nodes with IMRT

Challenge: Independent movements of prostate vs nodes

Courtesy of Ping Xia, UCSF 2007
ADAPTIVE STRATEGY using Daily MVCBCT for Pelvic Nodal Irradiation in the Treatment of Prostate Cancer

1- CT-MVCBCT registered on bony structures: -> patient aligned accordingly: setup error

2- CT-MVCBCT registered on gold markers -> prostate shift is the difference between these two alignments

3- Select and treat with a (pre-calculated) plan according to relative prostate shift
   - Set of pre plans with iso shifts (iso)
   - Shifting selected MLC leaves (mlc)
   - Re-optimization of the plan (reopt)

Breast daily alignment with contra-lateral breast dose sparing

• Start and stop angles of a cone beam acquisition are derived from the system registry
• Angles can be chosen to minimize dose to specific organs; e.g. CL-breast, Heart, etc.
• Only a 200 arc required

Images courtesy of Dr Geffen, Svanagh
MVCB Digital Tomosynthesis

MVCBDT is a limited arc MVBCT (20°-40° vs. 200°)

**Portal imaging**

2D
- low contrast
- fast acquisition
- (few seconds)
- 1-3 MU

**MVCBDT**

Some 3D
- Better contrast than EPID
- faster acquisition and lower dose than CB

**MVCBCT**

True 3D
- longer acquisition
- (~1 minute)
- 2-10 MU

Limited reconstruction arc results in tomographic noise, which increases as the arc decreases:
- Out of focus structures are reconstructed on the plane of interest ➔ slice thickness
- Shape distortion
- Image artifact from different densities materials

Courtesy of M. Descovich, UCSF
**Clinical Images**

<table>
<thead>
<tr>
<th>EPID</th>
<th>DTS 40°</th>
<th>MVCBCT</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="EPID Image" /></td>
<td><img src="image2.png" alt="DTS 40° Image" /></td>
<td><img src="image3.png" alt="MVCBCT Image" /></td>
</tr>
</tbody>
</table>

EPID: only 2D information, poor contrast  
DTS: spatial blur, better contrast  
CBCT: thin slices, improved contrast

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**MVCB DT: Conclusions**

- Image quality in DT depends on the reconstruction arc
- MVCB DT image quality is sufficient to provide anatomical information and might be suitable for registration purposes.

**Advantages:**
- Only a portion of the patient body gets exposed
- Faster
- Smaller dose

**Possible clinical application: lung patients**
- Reduce the motion blur in imaging moving targets
- Acquire images during breath-holding
- Online verification of 4D and respiratory gating techniques

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**Characteristics of megavoltage cone-beam digital tomosynthesis**

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- Imaging Beam Line (Diamond View)
- Accurate Dose Recalculation and the DGRT Process

Optimizing Image Quality:
New Imaging Beam Line (IBL)

**REMOVE FLATTENING FILTER**
- non-uniform illumination
- smaller focal spot size
- do not filter out low-E photons

**USE CARBON TARGET**
- generate more low-E photons

**REDUCE BEAM E TO 4 MEV**
- generate more low-E photons

Courtesy of B. Faddegon, UCSF-2007
Requirements for Dose Recalculation

- **Stability of CT Number**
  - Time
  - Target location
  - Patient size
  - Imaging dose

- **Complete Anatomy**
  - Longitudinal + lateral directions

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Accurate Dose Recalculation and the DGRT Process

Is the initial plan still valid?
When to replan?
What is the dosimetrical impact?

DGRT is based on the Availability of the 3D Dose Distribution “of the Day”
Accurate Dose Calculation can be obtained with MVCBCT

Morin et al., IJROB. 67(4),1202-1210; 2007.

Dosimetric impact and when to replan?

Week 1

Week 3

VD5+ (%)

Dose difference (%)
Clinical studies

H&N: Variation from planning dosimetric endpoints of the parotid glands and spinal cord.

Table 1. Statistics on the variation (%) from planning dosimetric endpoints of for H&N patients.

<table>
<thead>
<tr>
<th></th>
<th>Spinal cord D1 mean dose</th>
<th>Lt Parotid mean dose</th>
<th>Rt Parotid mean dose</th>
<th>Mandible D1</th>
<th>Brain Stem D1</th>
<th>Lt TMJ D1</th>
<th>Rt TMJ D1</th>
<th>Larynx mean dose</th>
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<tbody>
<tr>
<td>Mean</td>
<td>2.2</td>
<td>6.9</td>
<td>18.0</td>
<td>1.8</td>
<td>1.1</td>
<td>-1.6</td>
<td>-0.5</td>
<td>6.7</td>
</tr>
<tr>
<td>STD</td>
<td>2.9</td>
<td>9.5</td>
<td>18.0</td>
<td>4.1</td>
<td>2.7</td>
<td>8.0</td>
<td>5.1</td>
<td>9.3</td>
</tr>
<tr>
<td>Min</td>
<td>-3.3</td>
<td>-4.2</td>
<td>-2.1</td>
<td>-6.1</td>
<td>-4.8</td>
<td>-16.0</td>
<td>-12.3</td>
<td>-11.5</td>
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<tr>
<td>Max</td>
<td>10.7</td>
<td>37.9</td>
<td>51.8</td>
<td>12.2</td>
<td>10.1</td>
<td>19.0</td>
<td>5.2</td>
<td>25.4</td>
</tr>
</tbody>
</table>

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Availability of the Dose Distribution “of the Day”

- **Assess the dosimetrical impact**
  e.g. Patient setup, Anatomical change, Tumor shrinkage, Weight loss, etc.

- **Global quality assurance “in-vivo”**
  e.g. Treatment documentation

- **More Precise (Delivered-)Dose Response vs Outcomes**

- **Enables Dose-Guided Radiation Therapy**
  DGRT is an extension of ART where dosimetric considerations constitute the basis of treatment modification and validation.

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