Calypso 4D Localization System® and Prostate Motion Management

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Disclaimers

• I am not here to endorse products.
• I do not have any financial interests in the companies referred to in this presentation.
Intra-Fraction Motion

• After localization, we’re still looking for ways to track the prostate during treatment
• There is a push to finish treatments in “2 minutes” by most of the major RT manufacturers
  – If treatment times are reduced <2 minutes, then the need for tracking decreases, but not eliminated.
  – Arc therapy is not a substitute for a motion management system
• If tracking the prostate is not an option, rectal balloons may be used to reduce motion
Tracking Techniques

- robotic radiosurgery

- Prostate motion monitored by periodic x-ray imaging
Tracking Techniques

• Fluroscopic imaging of markers
Tracking Techniques

- Calypso®
- Beacons implanted and positions monitored by the system
- Monitors inter-fraction and intra-fraction motion
Calypso®
A Deeper Look

• FDA approved for prostates and prostate beds
• Eventually will be used for other anatomical sites
• We commissioned a unit at St. Luke’s Medical Center in August, 2008
How does it work?
The Beacons

The Array

- Attenuates 1-2% of the primary beam when beam is normal to the array
- Array source coils emit frequencies between 275 and 550 kHz
Calypso® Candidates

• Size
• No metal
• No pacemakers and defibrillators

<table>
<thead>
<tr>
<th>Prostate position from anterior surface</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 17 cm</td>
<td>Localize and track</td>
</tr>
<tr>
<td>17-23 cm</td>
<td>Localize only</td>
</tr>
<tr>
<td>&gt;23 cm</td>
<td>Not a candidate for the Calypso System</td>
</tr>
</tbody>
</table>

Other patient selection criteria includes:
• No prosthetic hip replacements
• No other metal objects in the pelvic region
• No pacemakers and defibrillators
Evaluation

• There must be 17 cm of clearance between the centroid of the beacons and the patient’s anterior surface

• Can use CT Sim, TPS, or other imaging system to evaluate prostate depth

• Watch out for large bellies!
  – Try treating prone

• We print screen and have signed by physician
Implant in Urology

- Beacons larger than gold seeds (for Acculoc)
- Urologists will be trained by Calypso
- Use 14 gauge needles
- Unique frequencies identify locations
- Up to 3 beacons may be implanted
Treatment Planning

• Dosimetry will contour each beacon and name according to specified convention
• Plan may be exported, parsed, and converted to a text file with an executable provided by Calypso
• Text file is exported and imported into the Calypso system.
Room Setup

- Camera “hub” and radiation detector
- Wall connections
- 3 Cameras
Couch Overlay

- Carbon fiber = interference
- Standard Varian couch interferes with Calypso
- 3-piece Kevlar overlay
- Varian “tennis-racquet” removed
Setup ("Localize")

- Array positioned
- Beacon location determined
- Compared to expected
- User alerted if thresholds exceeded
- Thresholds set by admin.

**Initial Setup**

<table>
<thead>
<tr>
<th>Item</th>
<th>Limit</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intertransponder distance</td>
<td>2 mm</td>
<td>Notify physics. Notify physician after 3 occurrences</td>
</tr>
<tr>
<td>Intertransponder distance</td>
<td>5 mm</td>
<td>Notify physics and physician</td>
</tr>
<tr>
<td>Rotation</td>
<td>10 degrees</td>
<td>Notify physics.</td>
</tr>
</tbody>
</table>
In-Treatment Thresholds

- Update rate is 10 Hz
- Beacon position monitored during treatment
- User alerted when out of bounds
- Patient-specific thresholds can be ordered and setup by admin.

### Treatment thresholds

<table>
<thead>
<tr>
<th>Item</th>
<th>Threshold</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left, Right, Superior, Inferior, and Anterior Shifts</td>
<td>5 mm for 15s or 10mm</td>
<td>Stop beam and realign patient</td>
</tr>
<tr>
<td>Posterior shift</td>
<td>3 mm for 15s or 7mm</td>
<td>Stop beam and realign patient</td>
</tr>
</tbody>
</table>
Prostate movement
Continuous Drift
Prostate Movement
Transient Excursion
Prostate Movement Excursion

Radiation Detected = Shaded Areas

Seconds
Prostate Movement
Low Frequency
Prostate Movement with Breathing
Therapist Repositioning

Therapists repositioned patient
Reports

- Both daily and trend reports are available
Ease of Use

- Relatively easy to learn
- Audible beeps alert therapist to organ motion
- Faster than CBCT to set up patient
Required QA

- Daily QA (therapist 5 min.)
- Monthly QA (physics 15 min.)
Tracking Modes

- Depending on the size of the patient:
  - Localize only
  - Localize and track

- Depending on the beacon placement
  - Isocenter mode (accounts for rotations; the preferred mode)
  - Centroid mode
    - Too collinear
    - Isocenter outside of the centroid region
    - Only 2 beacons available for tracking
Backup Plans

If Calypso computer goes down

- Use seed matching
- Match beacons with reference image
Intrafraction Motion Statistics

- Prostate treatments only
- MD Anderson Orlando has two Calypso units
- 30 patients – 1157 fractions analyzed
- 3mm excursion occurred during treatment in 41% of all fractions
- 5mm excursion occurred during treatment in 15% of all fractions

Our Experience

• We’ve treated 32 Calypso patients
• One challenge is to make sure we don’t implant beacons in patients who aren’t candidates because of their size.
• Another challenge is dealing with rotation warnings during the initial localization
• With our thresholds, we have to interrupt treatments 15% - 20% of the time
• Physicians have started reducing margins and escalating dose.
  – 190cGy x 43 = 8170 cCy
  – 7mm margins except 3mm posterior
Benefits

• More accurate treatment delivery with real-time tracking
• Faster patient setup and positioning
• More objective than radiograph matching or ultrasound localization
• May allow planning margins to be decreased, reducing toxicity to normal tissue
• May allow for dose escalation
Disadvantages

- Not all patients are candidates for tracking (too large, metal implanted, pacemakers)
- Presently, there is no interface to the LINAC for gating
- Modules must be purchased separately for different anatomical sites
- Beacons don’t show up well on MV portal images
Challenges in tracking

• One challenge of tracking tumors is the fact that, while the beam tracks the tumor, it may “untrack” critical structures.
  – Structures that do not move during breathing will appear to move relative to the radiation portal.
  – An understanding of the critical structure dose during the tracking process will be important

• Lag time
  – Robots, MLCs, and couches can only move at a certain speed
  – Tracking systems will need to “think ahead”
The Future of Calypso

- Automatic couch movement
- Automatic Linac gating
- MLC leaf tracking
- Enhanced arc therapy
- Other sites
  - breast
  - lung
- Calypso + CyberKnife
- Calypso + Protons
What’s Left for Prostate Motion Management?

- Moving beyond geometric based treatments to account for biological models of tumor response
- Adaptive radiation therapy accounting for changes in anatomy during the course of treatment
- Bigger and better particles to treat with (at a reasonable cost)
Questions?