Case Study: Use of deformable image and dose registration in the re-treatment of locally recurrent breast cancer

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Ballard Campus
Ballard Radiation Treatment Center

- Satellite freestanding single vault TomoTherapy in Ballard district of Seattle
- Part of large hospital system with 5 radiation locations
- Installed TomoTherapy Hi-ART in Jan 2011
- Upgrade to TomoEdge / VoLo Sept 2013
- Breast cancer represents almost 40% of our volume

“Extraordinary care, Extraordinary caring”
Objectives:

- Learn how deformation tools can be used in the clinic
- Underscore technical difficulties in treatment of recurrent aggressive breast cancers
- Demonstrate how image & dose deformation were used in planning this difficult case
Patient Details

- 53yo woman with biopsy proven breast cancer recurrence in Rt IMC nodes, extensive prior treatment
- Treated three courses at outside facility
- Four prior different positions
- Presents to us at third recurrence for fourth course of RT
- Referred to us to see if IMRT even possible given prior dose

Deformable Dose Accumulation & Helical IMRT
Challenges:

- Multiple prior courses of treatments on both sides
- Multiple treatment positions used

Dosimetrist’s Tasks

1. Review prior records from outside facility
2. Summarize prior doses and treatment positions
3. Assign those doses to the proper tissues and build a meaningful composite of all prior doses
4. Evaluate whether further treatment can be safely delivered
Overview and discussion of Deformable Image and Dose Registration
Deformable image registration

Deformable image registration ensures to reduce geometric differences between the two image data sets, by estimating the spatial relationship between the volume elements of corresponding structures.
Deformable image registration Considerations

- Every case is unique.
- Evaluation of deformation accuracy is critical.

- IAEA and AAPM recommend combined objective and visual methods for evaluating registrations. We use MIM Software’s RegReveal & RegRefine tools within MIM Maestro for this purpose.
Deformable dose registration

Dose is tied to CT image voxels, and follows them through the deformable image registration process. Attempts to show how a particular dose voxel has moved through positional changes since the dose was delivered.

Does NOT show the resulting change in dose due to morphologic changes that occur DURING treatment course.

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Deformable dose registration

ASTRO IMRT Documentation Working Group:

Recommends that RTP systems support deformable registration of previously treated dose distributions to the current axial image sets and furthermore, that these systems provide the capability to convert the deformed dose into an avoidance ROI to assist in planning a retreatment using either forward or inverse planning techniques.
Deformable dose registration

Not appropriate for use in adaptive planning to determine resulting dose to ROIs due to weight loss & morphology changes.
Deformable Registration for Adaptive Planning

Using the deformation engine to deform images and contours from one dataset to another IS an important use of deformable registration.

Example: Head & Neck planning and weight loss

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Image & Dose Deformation Summary

- Understand that this is a controversial topic in RT
- Be careful and understand potential risk
- Must have consensus between physician, physicist and dosimetrist regarding the validity of resulting data
- There can be considerable value if used carefully and thoughtfully in appropriate cases
- Beware of blindly trusting deformation algorithm results
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August 2009

Initial Diagnosis

Dx: Left Breast Cancer
  Triple negative
  BRCA 1 positive
  T1\textsubscript{b} N3\textsubscript{b} M0

Mastectomy

Neoadjuvant Chemotherapy

Comprehensive Radiation Therapy

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March 2010  At outside clinic:
First course of Radiation Therapy

- Reverse Hockey Stick technique (fields #1-7)
- Position:
  Supine, elevated, breastboard
  Lt arm up, Rt arm at side
- Lt SCF & Axilla: 4500cGy / 25fx
- Lt Chestwall: 4680cGy / 26fx
- Lt IMC Nodes: 5040cGy / 28fx
- Lt Scar (total): 5680cGy / 31fx
'Extraordinary care, Extraordinary caring'
“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
August 2010

Surgery

- Right skin & nipple sparing prophylactic mastectomy
- BRCA1 positive
- Strong family history of breast cancer

“Extraordinary care, Extraordinary caring”
March 2011

At outside clinic:

First Recurrence:
Second course of Radiation Therapy

- Recurred in Right Axilla
- 12 months post completion of RT course #1
- Tangents matched to nodal obliques (fields #8 – 11)
- Position:
  - Supine, elevated, both arms above head
- Rt SCF & Axilla 4680cGy / 26fx
- Rt Chestwall 4680cGy / 26fx
“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
Registration: Course 1 to Course 2

- Course 1: Supine and left arm raised
- Course 2: Supine and both arms raised

“Extraordinary care, Extraordinary caring”
Registration: Course 1 + Course 2

Start with simple rigid registration

Use focus box to concentrate on area of particular interest

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RegRefine

Start locking down points of agreement

These will influence and guide the deformation

Iterative process, can run it as many times as necessary

“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
Composite Isodose: Course 1 + Course 2

“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
May 2011

At outside clinic:

Second Recurrence
Third course of Radiation Therapy

- Recurred in Left Ant+Lat+Post Chestwall
- 2 months post completion of RT course #2
- Multiple electron fields #12-15
- Position:
  Lateral decubitus, both arms up
- Dose: 5640cGy / 31fx
Lateral Decubitus “rolled” position

Multiple matching electron fields #12-15

“Inflammatory” presentation

“Extraordinary care, Extraordinary caring”
"Extraordinary care, Extraordinary caring"
May 2011

At outside clinic:

Second Recurrence
Third course of Radiation Therapy

- Matching electron field #16
- Position:
  Prone, Lt arm up, Rt arm down
- Dose: 600cGy / 3fx
Prone position field #16

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“Extraordinary care, Extraordinary caring”
January – March 2012

Wound healing issues

Hyperbaric Oxygen treatments for Lt axillary wound healing

60 treatments

“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
October 2012  At BRTC:

Third Recurrence  Fourth course of Radiation Therapy

- Recurred in Rt IMC node chain
- 5 months post completion of RT course #3
- Helical IMRT  Field #17
- Position:  
  Supine, both arms up
- Dose: 6300cGy, 35fx
Why Helical IMRT for this case?

- Delivery to entire volume in one continuous field, no size limits or junctions
- Overlapping helical strips provide for very high degree of modulation
- Integrated system without import/export problems
- Dual laser system eliminates human error in performing setup “shifts”
- CT imaging daily allows daily registration to heart and lung position
- Very low “head scatter” compared to conventional linacs; no flattening filter

“Extraordinary care, Extraordinary caring”
Helical Delivery
Fusion of a Linear Accelerator and a Helical CT Scanner

“Extraordinary care, Extraordinary caring”
Helical TomoTherapy™
A unique beam delivery technique enabled by unique technology

- Fast Binary MLC
- Continuous Gantry Rotation
- Simultaneous Couch Movement

- MLC leaves that move at 250 cm/s to open or shut in milliseconds
- Thousands of beamlets throughout multiple 360 degree rotations
- Coverage of a target extent up to 160 cm in length with no matching

“Extraordinary care, Extraordinary caring”
Imaging Dose:

Coarse (6 mm) = ~ 0.3 cGy
Normal (4 mm) = ~ 1 cGy
Fine (2 mm) = ~ 2.5 cGy

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Target Delineation

Deformable registration of diagnostic PET-CT to planning CT
Adjustment for PET acquisition breathing artifact
Reasonable expansion for PTV
Outlined before prior dose accumulation done; no influence

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“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
Final Prior Dose Composite

Transfer and final deformation of all prior doses to our new planning scan

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Deformed Composite Dose: First 3 Courses, 3 Positions

Course 1: Left C/wall & Nodes "Reverse Hockey Stick"
Course 2: Right C/wall & Nodes FIF tangents, SCF, PAB
Course 3: Left C/Wall recurrence Multiple matched electron fields

Course 1: Supine, Left arm up, Right arm down
Course 2: Supine, both arms up
Course 3: Lateral Decubitus position

“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
“You want to do what?!”

<table>
<thead>
<tr>
<th>Rx Site: Right IMN Chain</th>
<th>Status: Approved</th>
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<tbody>
<tr>
<td>Technique: IMRT</td>
<td></td>
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<tr>
<td>Modality: X- 6MV</td>
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<tr>
<td>Dose Spec: Plan</td>
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<table>
<thead>
<tr>
<th>Rx Dose</th>
<th>Fractional Dose</th>
<th>Number of Fractions</th>
<th>Fractionation Pattern</th>
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<tbody>
<tr>
<td>6300 cGy</td>
<td>180 cGy</td>
<td>35</td>
<td>Daily</td>
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</tbody>
</table>

Total Cum: 6300 cGy

Only known site of disease.

“Extraordinary care, Extraordinary caring”
Helical IMRT Treatment

Supine
Both arms up
Custom Vac-Lok in wingboard
Treated “Feet First”

“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
What makes me think we can treat this plan accurately?

“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
Final Composite All Delivered Doses

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“Extraordinary care, Extraordinary caring”
“Extraordinary care, Extraordinary caring”
Current status of patient

- Remains on systemic therapy
- 2 serial PET-CT scans negative
- 18 months post completion of last radiation therapy course
- 4 years, 10 months since diagnosis

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Image and dose deformation in the clinic

- Feasible for use in the clinic
- Still labor intensive, takes practice for difficult cases
- Can be tremendously helpful in complex re-treatment situations such as this one
- Understand what it’s doing – QA and verification
- Realize that it’s an approximation of cum. dose