Experience with Helical IMRT in the treatment of Locally Advanced Left Sided Post-Mastectomy Breast Cancer

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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
Objectives:

- Describe challenges in treating these patients
  Review some historical methods and shortcomings

- Learn why helical IMRT might be a good option
  How does helical IMRT work?
  Which patients might it be appropriate for?

- Share our planning goals
  Where did we get our goals?

- Share our planning process

- How did we do? Did we meet our goals?

- Share some interesting cases

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“Locally Advanced Left Sided Post-Mastectomy Breast Cancer”

Involving:

- Entire Chestwall
- Supraclavicular Nodes
- Axillary Nodes
- Internal Mammary Nodes
- Generally high risk aggressive cancers.

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Locally Advanced Left Sided Post-Mastectomy Breast Cancer

Helical IMRT Patient Series

- 28 Sequential Cases
  January 2011 to present
- Average age 55 years (34-88)
- All with IMC involvement
- 3 patients with concurrently treated oligometastases

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Historically challenging and unrewarding to plan

- Large and irregular shape target
  - Convex shape
  - Difficult to achieve homogeneity
- Sensitive ROIs
  - Heart
  - Lungs
- Active disease may involve junction
  - Hot spots, Cold spots

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Special Cases

“Organ sparing is very important, but our first job is to effectively treat the cancer, and these are very bad cancers.”
Tangents matched to standard nodal fields

Potential Pitfalls:
- Incomplete IMC coverage
- Matchline across tumor
- Difficult to achieve coverage without exposure of lung and heart

Advantage:
- Can be used with gating

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Potential for inadequate IMC coverage

- “ABC” tangents with medial electron strip
- Difficult to reach deep aspect of IMC node chain

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Reverse Hockey Stick technique

Potential Pitfalls:
- Electron dose exit through lung
- Junctioning across tumor

Advantage:
- Relatively easy setup
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Potential Advantages to Helical IMRT

- 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

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Overview of TomoTherapy
Helical IMRT

- CT style slip-ring gantry mounted linac
- Fan beam, up to 40cm wide, divided into 64 “beamlets” by the multileaf collimator
- Helical delivery process to deliver IMRT 6 MV for treatment, 860 mu/min
- Same hardware used to image patient (IGRT) 3.5 MV for imaging, 20 mu/min
- Inverse planning system with integrated database
Helical Delivery
Fusion of a Linear Accelerator and a Helical CT Scanner

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Specific Terms for TomoTherapy

- **Beamlet**: A single leaf opening at one projected angle. There are 64 leaves, each .625cm at isocenter, 51 projections. A leaf is either open or closed (millisecond traverse time).

- **Pitch**: The fraction of the fan beam primary jaw opening advanced by the treatment couch per gantry revolution.

- **Modulation factor**: Ratio of longest leaf open time in a plan divided by the average open time of all non-zero leaf opening times.
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

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Why Helical?

Axial correct table indexing

Axial 0.2 mm error in table indexing

Helical pitch 0.5

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Helical Delivery Benefit: Resolution over width

“Width”

Pitch = 1

Gantry motion

Single “beam” with 5 “beamlets”

In this example:
51 angles x 5 beamlets x 6 rotations = 1530 total beamlets

Note: Effective beamlet width is reduced due to close angular spacing

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Helical Delivery Benefit: Resolution over length

“Length”

Pitch = 0.5

Single “beam” with 5 “beamlets”

In this example:
51 angles x 5 beamlets x 11 rotations = 2805 total beamlets

Note: Effective beamlet width and height is reduced due to close angular spacing and small pitch

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One beam angle with Tomo

Modulation of individual beamlets

One beam angle with VMAT

Weighting of broad beam apertures

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CT Based IGRT Process

Imaging Dose:

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

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Challenges with Helical IMRT

- Not compatible with respiratory gating ("RPM", "ABC")
- Low dose scatter and exit dose outside tx volume (same with static IMRT, VMAT, RapidArc)
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Ideal Planning Target Goals:

- 95% of **PTV_CW** receives 50.4Gy in 28 fx (1.8Gy/fx)
  Occasionally accept 90-92% coverage in extreme cases
  “Hard Constraint” in Tomo planning system
  PET-positive IMC nodes included in 50.4Gy volume

- 95% of **PTV_Nodes** receives 48Gy in 28 fx. (1.71Gy/fx)
  Instead of stopping nodes before CW
  Can use 1 plan for entire course, no additional QA
Ideal Planning OAR goals:

- **LAD:** < 10Gy
- **Lt Ventricle:** < 10Gy
- **Heart (other):** Max = 20Gy
- **Lung_LT:** V20<20%  V5<50%
- **Lung_RT:** Max = 5Gy
- **ContraBreast:** Max=10Gy

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Cardiac Considerations

- Marks et al: if >5% of LV included in field, incidence of perfusion defects increases from 10-20% to 50-60%
- Darby US SEER study: Increased cardiac mortality risk (RR~2.5) associated with left sided breast + IMC radiotherapy
- Correa et al: Stress test abnormalities in patients with left sided cancers higher than right, in the distribution of LAD
Breast XRT Cardiac Damage

- For most techniques, the greatest radiation doses were received by the anterior part of the heart and the left anterior descending coronary artery (LAD)

- Perfusion defects are specifically in the distribution of the left anterior descending (LAD) coronary artery

- LAD is a common site of atherosclerosis causing myocardial infarction.

* "Respiratory motion of the heart and positional reproducibility under active breathing control Pierce LJ, Ann Arbor"

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Pulmonary Considerations

Radiation Pneumonitis

- Most common pulmonary toxicity
- May be chronic
RT-Induced Pneumonitis

- Symptomatic RP in 1-5% of breast XRT
- No absolute “safe” MLD below which there is no risk of RP
- Patients younger than 65yo generally lower risk of RP
- MLD is a less reliable predictor for RP in IMRT
- Bilat $V_{20Gy} \leq 30-35\%$ and MLD $\leq 20-23\text{Gy}$ limits the risk of RP to $\leq 20\%$ in NSCLCA
- $V_{5Gy} < 60\%$; $V_{20Gy} < 4-10\%$; MLD $< 8\text{Gy}$ recommended for post-pneumonectomy mesothelioma patients undergoing XRT

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Materials and Methods

- TomoTherapy HiArt upgraded to VoLo and TomoEdge
  85cm wide bore
- GE Lightspeed CT Scanner
  standard bore
  2.5mm scan thickness
  shared with hospital ED
- Indexed “WingBoard” + VacLoc
- Bolus only for inflammatory or proven lymphodermal invasion
- MIM Maestro contouring & fusion software
A bit about skin dose…

- Beamlets are tangential over entire surface
  Clipped target 2.5mm from surface to avoid over optimization at skin

- Used TLD dosimetry to verify on the first several cases

- Bolus in place for simulation & treatment

- Variations in skin surface registration can lead to significant changes in skin dose.
PTV 5mm Clip – Skin Dose

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Greensboro, NC

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Targets Contoured

- PTV_CW clipped at 5mm from skin
- PTV_Nodes clipped at 2.5mm from skin
- Following RTOG CoreLab Contouring Atlas
- Bolus used only for inflammatory or confirmed skin involvement

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ROIs Contoured

- Lung_RT
- Lung_LT
  - HD_Lung
  - LD_Lung
- Heart_Whole
  - Heart_LAD
  - Heart_LT Ventricle
  - Heart_ANT
- ContraBreast
- Humeral Head
- Spinal Cord
- Esophagus
- Avoid_Mediast
- Avoid_Medial

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Heart

- The heart is contoured from the level of the root of the aorta and pulmonary trunk down to the apex of the heart, and includes the pericardium, entire myocardium, and blood volume.
- Left Ventricle contoured
- LAD contoured from root of aorta to apex of heart the LAD can be visualized directly, and its position can also be ascertained according to its location overlying the interventricular septum

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Samples of Isodose Plans

- Planning objectives applied
- Sometimes achievable, sometimes not
- Resulting treatment times average 8-11 minutes
- Require double time slot (30 minutes)
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Cardiac OAR Goals: How did we do?

- LAD: < 10Gy
- Lt Ventricle: < 10Gy
- Heart (other): Max = 20Gy

- V10Gy mean = 23%
  V15Gy mean = 6%
- V10Gy mean = 35%
  V15Gy mean = 8%
- V20Gy mean = 7%
  Mean dose = 10.3Gy

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Heart (whole) Dose DVH

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Lung OAR Goals: How did we do?

- Lung_LT: V20<20% V5<50%
  - V20Gy mean = 23%
  - V5Gy mean = 60%
  - Mean dose = 13.1Gy

- Lung_RT: Max = 5Gy
  - V5Gy mean = 11%
  - Mean dose = 3.2Gy
Ipsilateral (left) Lung Dose DVH

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Ipsilateral (left) Mean Lung Dose

Mean (av.) Ipsi.Lung (Gy)

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Contralateral (right) Lung Dose DVH

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Contralateral (right) Mean Lung Dose

Mean (av.) Contra Lung (Gy)

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ContraBreast OAR Goals: How did we do?

- ContraBreast: Max=10Gy
- V10Gy = 22%
- V15Gy = 9%
Skin dose results

- Inflammatory
- 48Gy to nodes / 28 fx clipped 5mm from skin
- 50.4Gy to chestwall / 28fx
- 10Gy boost to scar / 5fx (also helical IMRT)
- 3mm bolus daily on chestwall region

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Take home message

- Our goals are valid
  They are “goals”, not requirements

- Achievable in many cases
  Goals should push you to the best solution each time

- TomoDirect (static beam delivery) when possible
  The best way to avoid treating something is don’t aim at it!

- Lots of anatomic variation makes comparison difficult

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Conclusion and continuing goals

- Steep learning curve
  - Try to beat dose constraints, not just meet them
  - Be aware of what is achievable with a technology

- Not for every left sided case, but a great tool in the arsenal

- Continue to limit dose outside target
  - Specifically contralateral breast

- Keep it in context of individual patient’s age and disease

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Thank You!

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