IMAGE GUIDED RADIOTHERAPY IN CARCINOMA PROSTATE

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WHAT IS THE MOST ACCURATE TECHNIQUE OF RADIOTHERAPY?

Those who precisely know the answer, please raise their hands.
WHAT IS IGRT?

Those who precisely know the answer, please raise their hands.
• KVCT
• MVCT
• Positive biopsy after RT-19-65%

• The rate of positive biopsies decreased linearly as dose escalated (by 3DCRT)
  
  81 Gy-7% pos biopsy rate,
  
  75.6 Gy-48%,
  
  70.2 Gy-45%,
  
  64.8 Gy-57%

DOSE ESCALATION ➔ IMPROVED RESULTS

**MDACC**

4 YR PSA free survival rates:

- $<$67 Gy-(n=500)-54%
- 67-77 Gy-(n=495)-71%
- $>$77 Gy-(n=132)-77%

IMRT GIVES IMPROVED CONFORMITY

- Improved clinical outcomes
- Less complications and side effects
- More effective treatment
- Cost efficient technology
- Reduced need for invasive procedures
IMRT - TOOL FOR DOSE ESCALATION

Table 1. Clinical Goals for 81 and 86.4 Gy Prostate IMRT Treatment Plans at MSKCC

<table>
<thead>
<tr>
<th>Structure</th>
<th>81 Gy Plan</th>
<th>86.4 Gy Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning target volume</td>
<td>Maximum dose ≤90 Gy</td>
<td>Maximum dose ≤96 Gy</td>
</tr>
<tr>
<td></td>
<td>≥90% of PTV must receive ≥77 Gy</td>
<td>≥85% of CTV must receive ≥86.4 Gy</td>
</tr>
<tr>
<td>Rectal wall</td>
<td>No more than 30% can receive ≥75.6 Gy</td>
<td>Same as 81 Gy plan</td>
</tr>
<tr>
<td></td>
<td>No more than 53% can receive ≥47 Gy</td>
<td>Same as 81 Gy plan</td>
</tr>
<tr>
<td>Bladder wall</td>
<td>No more than 53% can receive ≥47 Gy</td>
<td>Same as 81 Gy plan</td>
</tr>
</tbody>
</table>
EFFICIENT TREATMENT ALSO REQUIRES ACCURACY!

Radiation shaped to target but missing target

The right target
CAUTION

With tight margins being taken in highly conformal radiotherapy techniques there is a risk of precisely missing the target with organ motion.
PROSTATE MOTION

- Two phenomena potentially affecting radiation delivery in Prostate cancer
  (A) Motion
  (B) Deformation

- These changes can happen
  (A) Interfraction motion
  (B) Intrafraction motion
  (C) Interfraction deformation
PROSTATE MOTION

- Position depends on the status of rectal filling
- Is known to translate and rotate under influence of rectal filling changes
- Full rectum has mobile gas pockets, associated with increased prostate motion
- Apex is largely immobile
- Motion well described by rotation but undergoes deformation due to distension
PROSTATE MOTION
COMPARISON OF PATIENT ANATOMY ON SIMULATION AND TREATMENT DAY
INTERFRACTIONAL PROSTATE MOTION AMONG NORMAL, OVERWEIGHT, AND OBESE

Table 1: Summary of inter-fraction prostate shift for three patient subgroups

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Overweight</th>
<th>Obese</th>
<th>All patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractions</td>
<td>143</td>
<td>320</td>
<td>232</td>
<td>695</td>
</tr>
<tr>
<td>AP Shift (mm)</td>
<td>0.3 ± 4.1</td>
<td>−0.1 ± 5.3</td>
<td>0.7 ± 4.1</td>
<td>0.2 ± 4.7</td>
</tr>
<tr>
<td>LR Shift (mm)</td>
<td>0.5 ± 4.1</td>
<td>1.1 ± 2.9</td>
<td>−0.3 ± 5.5</td>
<td>−0.5 ± 4.0</td>
</tr>
<tr>
<td>SI Shift (mm)</td>
<td>0.0 ± 0.4</td>
<td>−0.1 ± 0.8</td>
<td>−0.2 ± 1.1</td>
<td>−0.1 ± 0.9</td>
</tr>
</tbody>
</table>

# INTRAFRACTION MOTION

<table>
<thead>
<tr>
<th>POI</th>
<th>Rectal status (mm)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full</td>
<td>Empty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apex</td>
<td>1.26</td>
<td>1.04</td>
<td></td>
<td>0.050</td>
</tr>
<tr>
<td>Inferior posterior</td>
<td>1.20</td>
<td>1.0</td>
<td></td>
<td>0.056</td>
</tr>
<tr>
<td>Midanterior</td>
<td>0.98</td>
<td>0.79</td>
<td></td>
<td>0.047</td>
</tr>
<tr>
<td>Midposterior</td>
<td>1.72</td>
<td>0.79</td>
<td></td>
<td>0.0001</td>
</tr>
<tr>
<td>Anterior base</td>
<td>1.38</td>
<td>1.04</td>
<td></td>
<td>0.009</td>
</tr>
<tr>
<td>Posterior base</td>
<td>1.44</td>
<td>0.85</td>
<td></td>
<td>0.0001</td>
</tr>
<tr>
<td>Seminal vesicles</td>
<td>1.56</td>
<td>0.68</td>
<td></td>
<td>0.0001</td>
</tr>
<tr>
<td>Pubis, inferior</td>
<td>0.45</td>
<td>0.62</td>
<td></td>
<td>0.981</td>
</tr>
<tr>
<td>Pubis, superior</td>
<td>0.41</td>
<td>0.54</td>
<td></td>
<td>0.988</td>
</tr>
<tr>
<td>Sacrum</td>
<td>0.40</td>
<td>0.42</td>
<td></td>
<td>0.688</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1.36</td>
<td>1.78</td>
<td></td>
<td>0.927</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Patient(s) (n)</th>
<th>Imaging method</th>
<th>Displacement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dawson (2000)</td>
<td>4</td>
<td>Fluoroscopy 3 Rx-opaque markers: apex</td>
<td>In normal breathing &lt;1 in all directions 0.9–5.3 in CC (prone)</td>
</tr>
<tr>
<td>Huang (2002)</td>
<td>20</td>
<td>Before and after Tx BAT ultrasound alignment on 10 Tx</td>
<td>Anterior 0.2 +/- 1.3 Superior 0.1 +/- 1.0 Left 0.01 +/- 0.4</td>
</tr>
<tr>
<td>Khoo (2002)</td>
<td>10</td>
<td>Sagittal and axial MRI</td>
<td>Axial Anterior 0.4 +/- 1.1, Posterior 0.5 +/- 1.7 Left 0.1 +/- 1.0, Right 0.1 +/- 0.9 Sagittal Anterior 0.2 +/- 0.9, Posterior 0.4 +/- 1.6 Superior 0.2 +/- 1.3, Inferior 0.1 +/- 1.2</td>
</tr>
<tr>
<td>Kitamura (2002)</td>
<td>10</td>
<td>Real-time fluoroscopy 1 marker (apex)</td>
<td>Supine AP 0.3 +/- 0.4, CC 0.3 +/- 0.2, LL 0.3 +/- 0.1 Prone AP 1.6 +/- 0.4, CC 1.4 +/- 0.5, LL 0.5 +/- 0.4</td>
</tr>
<tr>
<td>Mah (2002)</td>
<td>42</td>
<td>Cine MRI axial and sagittal No implanted markers</td>
<td>AP 0.17 +/- 2.9 Sagittal AP 0.26 +/- 3.3 Axial CC 0.02 +/- 3.36, LL 0.00 +/- 1.47</td>
</tr>
<tr>
<td>Author (year)</td>
<td>Patients (n)</td>
<td>Imaging method</td>
<td>Displacement (mm)</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------</td>
<td>-----------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Malone (2000)  | 40           | Fluoroscopy 3 gold markers (apex, posterior, Base)  | Prone + immobilization group Mean 3.3 +/- 1.8  
>=4-mm displacements AP 8% of pts, CC 23% of pts |
| Nederveen (2002)| 10           | Fluoroscopy Multiple markers but only 1 tracked     | AP 0.3+/-0.5 CC 0.4+/-0.7                                                       |
| Padhani (1999) | 55           | Axial cine MRI No implanted markers                 | Median AP 4.2 mm 74% of pts—mainly AP displacements 29% of them> 5 mm          |
| Shimizu (2000) | 10           | Fluoroscopy before and after Tx delivery 1 marker in tumor (9 pts) and near tumor (1 pt) | Median of absolute displacement AP 0.7, CC 0.85 LL 0.6                           |
| Vigneault (1997)| 2            | On-line EPID 1 marker (apex)                        | No displacement Observed                                                         |
The average volume change was 0.05 cm³/day, which was not significantly different from zero ($p > 0.05$)

HOW TO SOLVE THESE PROBLEMS?

3. Or Use IGRT

1. Use large margins, irradiating too much healthy tissues

2. Use small margins, and risk missing the target
IMAGE GUIDED RADIOTHERAPY

- IGRT refers broadly to treatment delivery using modern imaging methods like CT, PET and USG in target and non-target structures and in RT definition, design and delivery.

- It includes but is not limited to 3DCRT, IMRT, SRT, SRS & brachytherapy.
IGRT IN PROSTATE

IMAGE GUIDED EBRT

IMAGE GUIDED BRACHYTHERAPY
IGRT: AVAILABLE OPTIONS

IGRT encompasses the following present day Technology

- **Volumetric**
  - CT on rails
  - Tomotherapy
  - MV cone beam CT
  - KV cone beam CT

- **Planar X ray based**
  - EPID
  - Cyber knife

- **Video based**
  - Real Time video guided IMRT

- **Ultrasound based**
  - BAT
TECHNIQUES OF TUMOR TRACKING IN CA PROSTATE

• Skin Markers

Not adequate for IGRT as margins required will be 1.5 –2cm

• Internal markers

A. Endorectal balloon
   Not very useful but can reduce rectal radiation dose
   Renders rectal dosimetry more predictable by making rectal anatomy more reproducible

B. Implanted fiducials
   Deformation is a problem with use of fiducials
   Less inter user variation
   Good marker stability

C. Implanted transponders for electromagnetic tracking

D. CT based Bony Anatomy tracking

E. CT based Soft Tissue Tracking
IMAGE GUIDANCE

- Online
  Daily image guidance with daily adjustments

- Offline
  Follow a certain imaging schedule and apply offsets on data when imaging not performed
IGRT AUTOMATIC BONE LOCALIZATION
HOW TO CORRECT FOR DISPLACEMENTS

- Couch corrections
- Gantry and collimator angle adjustments
- Modification of MLC leaf positions
COUCH CORRECTIONS

Correction by lateral couch shift (Tomotherapy)

COUCH CORRECTIONS
Comparison of rotated and corrected dose distributions (Tomotherapy)

ELEKTA SYNERGY-S IGRT AT AIIMS
6 DEGREES OF FREEDOM
• Gantry and collimator angle adjustments were used to correct for prostate rotation without rotating the table.
AN AUTOMATIC CT-GUIDED ART TECHNIQUE - ONLINE MODIFICATION OF MLC LEAF POSITIONS

INTRA-FRACTION AND INTER-FRACTION MOTION ASSOCIATED WITH SBRT AND IGRT

• 127 patients - 3 D CRT - total dose of 78 Gy

• Rectal distension = average cross-sectional rectal area (CSA; defined as the rectal volume divided by length) and measuring three rectal diameters on the planning CT.

Rectal distension decreased the probability of biochemical control, local control, and rectal toxicity in patients without daily IGRT.

Therefore, an empty rectum is warranted at the time of simulation.

Emphasize the need of empty rectum for IGRT to improve LC.

IMPACT OF IGRT ON OUTCOMES AFTER EBRT FOR LOCALIZED PROSTATE CANCER

• 488 pts treated with IGRT

• The radiation dose - 70 Gy at 2.5 Gy/fr

• Before each daily trt, alignment of the prostate was performed with BAT ultrasound system.

5-year b RFS rate for the rectal distention <50, 50 to <100, and >100 cm$^3$ groups was 90%, 83%, and 85% (p =0.18).

Rect dist was not an independent predictor of biochem failure (p = 0.80).

• Rect dist was also not a predictor of rectal or urinary toxicity

PHASE II TRIAL OF HYPOFRACTIONATED IGRT FOR LOCALIZED PROSTATE CA

• **Purpose:** Feasibility and late toxicity of hypo fractionated IGRT for prostate cancer.

• T1c–2cNXM0. 60 Gy in 20fractions over 4 weeks with IGRT with intra prostatic fiducial markers. 92 pts

• Grade 3–4 toxicity in only 1 patient. Biochemical control at 14 months was 97%. The incidence of late toxicity was low.

• **Hypo-fractionated IGRT is feasible** and is associated with low rates of late bladder and rectal toxicity. Biochemical outcome is comparable.

DOSIMETRIC EFFECTS OF THE PRONE AND SUPINE POSITIONS

• Soft-tissue alignment combined with 5 mm planning margins is appropriate in minimizing treatment planning and delivery uncertainties in both the supine and prone positions.

• Alignment based on bony structures showed improved results over the use of skin marks for both supine and prone setups.

• Under bony alignment, the dose coverage and PTV overlap index for prone setup were statistically better than for supine setup.
• IMAGE GUIDED BRACHYTHERAPY
Imaging modalities used in brachytherapy

- Fluoroscopy
- Ultrasound / TRUS
- CT scan
- MRI
ADVANTAGES OF IMAGING IN BRACHYTHERAPY

• Real time guidance for placement
• Avoidance of normal structures
• Better accuracy
• Improved treatment planning
IMBT

- Inverse Planning Simulated Annealing (IPSA)
  Inverse Planning in Brachytherapy
CONCLUSIONS

- Radiotherapy has a very important role in the management of carcinoma prostate

- Advances like 3D CRT, IMRT, IGRT and HDR has made dose escalation feasible

- Image guidance helps to decrease geometric uncertainties

- IGRT important for dose escalation

- Long term results awaited
Thank You