A new paradigm: Stereotactic Radiotherapy for Breast Cancer: *GammaPod™*

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I do not have anything to disclose.
• Clinical background

• Device Introduction
  – GammaPod
  – Immobilization Device & Image Loader

• Preliminary Performance Results
  – Reproducibility Study
  – Post-operative and pre-operative settings
  – Dosimetric comparisons


- **BCT established as standard of practice**

- **Comparable outcomes to mastectomy**

- **Better cosmetic results and reduced trauma**

*Fisher et al. NEJM 2002*
• **Whole breast RT**

• **Simple parallel opposed tangent beams**

• **Course of 5-7 weeks**

K. Asbury, 2012
Breast Toxicity

- Hepel et al. 2009

**Late Subcutaneous Fibrosis**

![Graph showing Late Subcutaneous Fibrosis](image)

**Cosmesis**

![Graph showing Cosmesis](image)

Hepel et al., IJROBP 2009
Pathological studies of multi-focality of the breast cancer improved understanding of disease extent...

Holland et al. Cancer 1985
- ~ 40% disease @ >2.0 cm away from the “otherwise would-be resections” in the mastectomy specimens

Ohtake et al. BCRS 2000
- < 10% cases with disease @ >2.0 cm

Faverly et al. Cancer 2001
- Residual disease unlikely @ >1.1 cm (<8%)
Partial Breast Irradiation

- Several “partial breast” irradiation techniques have been devised...

- External beam RT
  - IMRT & 3DCRT

- Brachytherapy
  - Interstitial and multi-lumen applicators
  - Balloon-based, single & multi-lumen
• External Beam RT
- **Mammosite**

*Major et al., Rad Onc 2006*
• Contura multi-lumen

Wilder et al., Brachytherapy 2009
Multi-Lumen

- SAVI

Fig. 2. Strut-Adjusted Volume Implants (SAVI) with simultaneous close proximity to (a) skin and chest wall and (b) dosimetry.

Yashar et al., IJROBP 2010
• Interstitial
• Accubooost
Problem(s) with Standard APBI

- Radiation following lumpectomy results in large volumes of normal tissue treated
  - NSABP-B39: 1.5 cm CTV & 1.0 cm PTV margin

- Can we give RT pre-operatively?

Nichols et al., IJROBP 2010
There are also other issues with standard PBI techniques
- Non-conformal irradiation
  - EBRT still tangents
  - Brachytherapy dose is very heterogeneous and poor dose fall-off
- Localization, setup, reproducibility difficulties
- Breathing motion etc.

Can we improve the technology?
• 36 sources spaced 1 degree apart laterally and 10 degrees longitudinally

• 2.5 cm & 1.5 cm collimator positions

• Source carrier & collimator rotates synchronously...

• Total 4400 Ci source produces ~5 Gy per minute for 2.5cm
Dose Distributions
Static Dose Shaping

Static ball packing of “shots” to create adequate target coverage ➔ Gamma Knife
Dynamic dose painting allows more high dose homogeneity and differential dosing...
GammaPod Dose Distribution
Stereotactic Principles

• Stereotactic level of targeting accuracy requires
  – Good immobilization of anatomy
  – Improved localization

• GammaPod Immobilization
  – Reduced motion with prone setup
  – Breast cup with vacuum suction
  – Automatic patient loading mechanism

• Localization
  – Radio-opaque stereotactic frame
**GammaPod Breast Cup**

- **Two-layered breast cup system**
  - 3 Outer cup sizes
  - 9 Inner cup sizes

- **Vacuum between the inner and outer cups...**

- **Built-in radio-opaque wire for stereotactic frame**
GammaPod Loader
• Improves integrity of breast immobilization between imaging and treatment sessions...
Study of Localization Accuracy

- U of Maryland IRB approved Localization Accuracy and Reproducibility Study

```
Prep → Imaging → Wait → Treatment → End
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CT #1
```

```
CT #2
```

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“Simulated”
Treatment Planning
```


## Timing of the Process

<table>
<thead>
<tr>
<th>Step</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Setup</strong></td>
<td>26”  [13 – 45]</td>
</tr>
<tr>
<td><strong>Dock &amp; Scan</strong></td>
<td>6”  [4 – 10]</td>
</tr>
<tr>
<td><strong>Registration</strong></td>
<td>3”  [1 – 7]</td>
</tr>
<tr>
<td><strong>Contouring</strong></td>
<td>6”  [2 – 13]</td>
</tr>
<tr>
<td><strong>Planning &amp; Finish</strong></td>
<td>8”  [6 – 14]</td>
</tr>
<tr>
<td><strong>Second Setup</strong></td>
<td>6”  [3 – 13]</td>
</tr>
<tr>
<td></td>
<td>31”  [13 – 45]</td>
</tr>
</tbody>
</table>
• Reproducibility of Internal and External Fiducials
• 20 patients accrued in the study...
  – 3 patients aborted the study due to comfort issues or setup difficulty...
  – 1 patient cancelled due to breast cup size mismatch (logistics)

• 16 patient scans were available for study...
  – 5 patients had pressure related issues
3D Reproducibility

External Fiducials
0.56 ± 0.67 mm

Internal Fiducials
2.11 ± 1.99 mm

No patient requiring small cup yet...
3D Reproducibility

Inside the Cup:
1.15 ± 0.92 mm (0.24 – 3.92 mm)

Outside the Cup:
4.26 ± 2.10 mm (1.62 – 7.92 mm)
Breast cup immobilizes the tissue within the cup sufficiently…

The anatomy outside the cup (for targets close to chest-wall) is prone to general patient setup errors.
GammaPod in Post-Op APBI
6 post-lumpectomy breast cancer patients (5 LT and 1 RT)

**PTV_EVAL**

- 3D-CRT
- IMRT
- GammaPod (10 mm)
- GammaPod (3 mm)

**Ipsi-lateral Breast**

- 3D-CRT
- IMRT
- GammaPod (10 mm)
- GammaPod (3 mm)

Hepel et al. ➔ V20 less than 60%
GammaPod in Post-Op APBI

6 post-lumpectomy breast cancer patients (5 LT and 1 RT)

Heart

Chest Wall

3D-CRT
IMRT
GammaPod (10 mm)
GammaPod (3 mm)
Comparison to APBI Brachytherapy

Table 2: Skin doses in % of PD. Mean skin doses for the BT devices and range within parentheses. Two values for GP – skin dose when the dose is normalized to 100% of PD at the target edge and skin dose obtained from the optimization (second one within square brackets).

<table>
<thead>
<tr>
<th>Skin distance (cm)</th>
<th>MS</th>
<th>CMLB</th>
<th>SAVI</th>
<th>GP 6.5 cm</th>
<th>GP 4 cm</th>
<th>GP 2 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>100 (100-100)</td>
<td>75 (73-77)</td>
<td>72 (71-74)</td>
<td>9 [6]</td>
<td>10 [9]</td>
<td>10 [7]</td>
</tr>
<tr>
<td>0.5</td>
<td>144 (137-144)</td>
<td>83 (82-84)</td>
<td>76 (74-77)</td>
<td>22 [13]</td>
<td>21 [18]</td>
<td>23 [20]</td>
</tr>
</tbody>
</table>
Potentially use dose-shaping capabilities of GammaPod

Deliver ablative dose to the gross tumor (GTV)
Example: High dose e.g. 3 x 20 Gy to GTV

Deliver sterilizing dose to tumor extension ~ GTV + 1.5 cm
Example: Low dose e.g. 3 x 8.5 Gy (~equiv. to 10x3.85 Gy)
**GammaPod in Pre-Op APBI**

- **Whole Breast Physical Dose (D) and Biologically Equivalent Dose (BED)**

![Comparison of Dose DVHs](image1)

![Comparison of BED DVHs](image2)
**GammaPod in Pre-Op APBI**

- **Uninvolved Breast NTCP** *(end point “moderate” fibrosis)*
  - GammaPod (SBRT) = < 0.1
    - EUD (2 Gy) = 5.5 Gy
  - APBI Post-Op (EXRT) = 1.2 %
    - EUD (2 Gy) = 24.5 Gy

*Assuming Lyman’s Poisson Model with NTCP parameters from Alexander et al.*
Current Status

- GammaPod was installed at U of Maryland in June 2014
  - Co-60 sources (2700 Ci) were installed in November 2014
- Preliminary dosimetry and commissioning work has started
  - First treatments expected in Aug 2015
- Studies coordinated through a consortium of 5 academic institutions
  - UMMS, UT Southwestern, Kansas, Allegheny and Ottawa
Commissioning Work

(a) and (b) diagrams showing dimensions and annotations such as "Film pocket", "Phantom in couch aperture", "Viewed from under couch", "Calibration point", "Vertical film pocket", and "Couch surface".

Courtesy of P. Hoban
Commissioning

Treatment Plan Measured vs Calculated Relative Dose

(i) (a) (b) (c) (d) (e) (ii) (a) (b) (c) (d) (e)
Thank You!