Intensity Modulated Brachytherapy Using Directional Sources

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Possibilities for intensity-modulated brachytherapy: technical limitations on the use of non-isotropic sources

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Partially-Shielded Sources

- $^{192}$Ir dose distributions
- Ignore scatter
- $45^\circ$ emission at various shield transmission levels

Effects of transmission on dose distribution:

Emission: $45^\circ \times 1$  $11.25^\circ \times 4$

IMBT Improves Tumor Dose Conformity Relative to HDR

Cervical Cancer

• 13,240 women estimated to be diagnosed with cervical cancer in the U.S. alone in 2018 (Siegel et al, 2018)

• For stage IB and higher tumors, standard treatment is Chemo + External Beam RT + Brachytherapy

• Brachytherapy boost is critical for tumor control

• Tumors are often irregularly-shaped, laterally-extended, and BT applicator not centered
How can IMBT Benefit Cervical Cancer Patients?

(including EBRT)
Intracavitary/Interstitial Approach to Improve Dose Distributions

The Intracavitary/Interstitial Approach Works

- RetroEMBRACE: Retrospective study completed prior to EMBRACE I (2008)
- Local control at 3 years for HR-CTVs ≥30 cm³
  - 92% at centers with IC/IS (n=169)
  - 82% at centers with IC only (n=118)
- Local control at 5 years:
  - 87% at centers with IC/IS (n=124)
  - 80% at centers with IC only (n=163)
- EMBRACE II: Launched in 2016
  - ≥20% of patients at a participating center must receive IC/IS

L. Fokdal et al, Radiother Oncol 120, 434-440 (2016)
Pötter et al, "The EMBRACE II study...” Clin Transl Radiat Oncol 9, 48-60 (2018)
Logistical Benefits of an Intracavitary Only Approach

• 25% decline in average number of residency-based IS brachytherapy procedures reported between 2006-2007 and 2010-2011 (Compton et al)

• 50% of Canadian centers with the capability to treat gynecological cancer patients with HDR-BT also have IC/IS capability (Gaudet et al)
  • Even so, <10% of residents and fellows reported being satisfied with the IC/IS training they received (Gaudet et al)
  • Opposite case for IC-only training: 70% satisfied (Gaudet et al)

• Numbers in US not available but unlikely more in favor of IC/IS than for Canada since U.S. centers tend to be less consolidated and more widely dispersed

Patent pending
RSBT Provides Excellent HR-CTV Dose Conformity

<table>
<thead>
<tr>
<th>Patient</th>
<th>ICBT</th>
<th>IS+ICBT</th>
<th>RSBT-180</th>
<th>RSBT-45</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.55 min</td>
<td>4.66 min</td>
<td>8.23 min</td>
<td>34.91 min</td>
</tr>
<tr>
<td>2</td>
<td>7.04 min</td>
<td>7.32 min</td>
<td>11.01 min</td>
<td>76.45 min</td>
</tr>
<tr>
<td>3</td>
<td>5.31 min</td>
<td>5.37 min</td>
<td>9.31 min</td>
<td>53.57 min</td>
</tr>
</tbody>
</table>

“Best” plan

EQD2 Dose, Unit: Gy

Yang et al, PMB 58, 3931-41 (2013)
RSBT Provides Excellent HR-CTV Dose Conformity

Yang et al, PMB 58, 3931-41 (2013)
Direction-Modulated Brachytherapy for High-Dose-Rate Treatment of Cervical Cancer. I: Theoretical Design

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192Ir based Direction-Modulated Brachytherapy

\[ {}^{192}\text{Ir} \text{ DMBT for Cervical Cancer} \]

Potential Benefits of IMBT for Prostate Cancer

- 160,000 new diagnoses expected in 2018
- 5-year relative survival rates for localized prostate cancer are >99%
- 30,000 deaths expected in 2018, 2nd highest for cancer death in men
- Treatments that improve convenience for the patient and maintain low toxicity without compromising effectiveness are attractive:
  - SBRT
  - Low-dose-rate brachytherapy
  - One-shot prostate cancer HDR

<table>
<thead>
<tr>
<th>Series (Last update)</th>
<th>Dose</th>
<th># Patients</th>
<th>Disease Risk</th>
<th>Median Follow-up</th>
<th>Biochemical Control @ Median F/U</th>
<th>Grade ≥ 3 Toxicity (%)</th>
<th>Grade ≥ 3 Toxicity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt. Vernon Hospital, UK (2017)</td>
<td>19 Gy x 1</td>
<td>23</td>
<td>Int, High</td>
<td>4.1</td>
<td>94%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>20 Gy x 1</td>
<td>26</td>
<td>Int, High</td>
<td>4.1</td>
<td>94%</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Santander, Spain (2016)</td>
<td>19 Gy x 1</td>
<td>60</td>
<td>Low, Int</td>
<td>6.0 y</td>
<td>66%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Toronto Sunnybrook (2017)</td>
<td>19 Gy x 1</td>
<td>87</td>
<td>Low, Int</td>
<td>2.25 y</td>
<td>92%</td>
<td>1.1</td>
<td>0</td>
</tr>
<tr>
<td>Oakland U., Michigan (2017)</td>
<td>19 Gy x 1</td>
<td>58</td>
<td>Low, Int</td>
<td>2.9 y</td>
<td>93%</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Phoenix definition of biochemical failure: PSA reaches nadir + 2 ng/mL

“Group” nadir

19 Gy x 1: 87 pts

13.5 Gy x 2: 83 pts

Morton et al, Radiother Oncol 122, 87-92 (2017)
Technology

Conventional High-dose-rate Brachytherapy

Rotating Shield Brachytherapy (RSBT)

Needle and Catheter Design and Prototypes

Needle/Catheter/Source Model

Prototypes

Catheter

Needle
Dose Escalation Achievable with RSBT

Conventional HDR

One $^{192}$Ir source
19 Gy in ~20 minutes

Proposed RSBT

Nineteen $^{153}$Gd sources
23 Gy in ~133 minutes
Same Urethral Dose
Dose Escalation of 23% Possible with RSBT
Multisource RSBT Apparatus: Angular Drive Mechanism

a. Angular drive mechanism, 0°

Prostate gland

Rectum

Translational motion

Prototype Construction

Images from Bounnak Thammavong
Prostate IMBT System Design from McGill (Enger) Group

Famulari et al (2018)
Conclusions

- IMBT has the potential to significantly improve dose distributions relative to conventional HDR.
- For cervical cancer, IMBT could eliminate the need for combined intracavitary and interstitial brachytherapy.
- For prostate cancer, IMBT could provide superior one-shot temporary brachytherapy to $^{192}$Ir-based HDR.
- An isotope other than $^{192}$Ir is needed for prostate IMBT.
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Questions?

Young Corn,
by (Iowan) Grant Wood (1931)