Developing a Treatment Planning System for Next Generation Rotating-Shield Brachytherapy

Xiaodong Wu

Department of Electrical and Computer Engineering
Department of Radiation Oncology
University of Iowa
IOWA, USA
Disclosures

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Funding Overview

Mechanism/Study Section
- PAR-13-137: Bioengineering Research Grants (BRG) (R01)
- Radiation Therapeutics and Biology Study Section

Grant Title: Developing a Treatment Planning System for Next Generation Rotating-Shield Brachytherapy

PI, Co-investigator Team
- Xiaodong Wu (PI) – ECE and Radiation Oncology
- Weiyu Xu (co-I) – ECE
- Yusung Kim (co-I) – Radiation Oncology
- Ryan Flynn (co-I) – Radiation Oncology
- John Buatti (co-I) – Radiation Oncology
- Mark Smith (co-I) – Radiation Oncology
Funding Overview

- Submission History
  - First submission (funded)
    - Impact score: 35
    - Percentile: 16.0
    - New investigator eligible: Yes
    - Payline: 12
    - Payline for the new investigator: 17
  - Did resubmission
Clinical Motivation/Significance

- What clinical problem are you solving?
  - Introduce/Implement the intensity modulation technique with High-Dose-Rate (HDR) brachytherapy

- Why is it important?
  - HDR can only generate symmetric dose distributions
  - Overdose OARs
  - Lowerdose laterally-extended tumors

Create asymmetric dose distributions!
Relevant Prior Experience/ Preliminary Data

- List if anything made you uniquely qualified to lead this work
  - Trained on computer algorithms and optimization
  - Worked on IMRT treatment planning optimization since graduate study
  - Worked on some fundamental algorithms for IMAT

- What preparation work did you do to be well positioned for funding?
  - A long research history on IMRT
  - Worked on RSBT treatment planning since 2010
Relevant Prior Experience/ Preliminary Data

Describe key preliminary data used in your grant submission

- Rotating a shielded source along the treatment path to deliver HDR BT can significantly improve the plan quality using appropriate plan optimization techniques.
Specific Aims

- **Aim 1**: Develop an efficient compressed sensing based RSBT inverse dose optimization method, enabling sparse intensity modulation and optimized homogeneity of dose distributions with smooth fluence maps in the resulting treatment plan.

- **Aim 2**: Develop efficient shield sequencing methods to optimize the delivery of RSBT treatment plans, striving to achieve the best tradeoff between plan quality and treatment time, and to facilitate clinicians’ decision making on selecting the best patient-specific treatment plan.

- **Aim 3**: Dosimetrically validate the RSBT treatment planning system retrospectively with clinical cases of cervical and prostate cancers previously treated with HDR-BT.
Preliminary or Key Scientific Outcomes

- Publications: 5 Med. Phys. + 3 Red Journal
- Needle-free cervical cancer RSBT applicator design
RSBT can provide superior dose distributions to IC/IS

- Intracavitary $^{192}\text{Ir}$
- Intracavitary/Interstitial $^{192}\text{Ir}$
- RSBT-45° + Ovoids $^{169}\text{Yb}$

### Isodose Lines (Gy$_{EQD2}$)

- Red: 125
- Yellow: 115
- Orange: 105
- Green: 95
- Cyan: 85
- Blue: 75
- Purple: 65
- Violet: 55

**Axial**
- HR-CTV Rectum

**Coronal**

- **Sagittal**

<table>
<thead>
<tr>
<th>D$_{90}$</th>
<th>Time</th>
<th>Isodose Lines</th>
<th>Gy$_{EQD2}$</th>
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<tr>
<td>69.4</td>
<td>7 min</td>
<td>Red</td>
<td>125</td>
</tr>
<tr>
<td>95</td>
<td>6 min</td>
<td>Yellow</td>
<td>115</td>
</tr>
<tr>
<td>105</td>
<td>52 min</td>
<td>Orange</td>
<td>105</td>
</tr>
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Cervical cancer RSBT

- $^{169}$Yb-based RSBT provided a greater percentage of the 37 patients considered with HR-CTV $D_{90}$-values of $85 \text{ Gy}_{\text{EQD2}}$ than IC/IS
- $^{169}$Yb-based RSBT median treatment times were 1/3 those of IC/IS
- Source age accounted for
- Needle placement and planning time accounted for
- The multi-shield approach is the key to ensuring rapid treatment times
Preliminary or Key Scientific Outcomes

- Prostate cancer RSBT
  - Major dosimetric advantage relative to conventional HDR-BT
    - 30.8% boosting on average ($n = 26$) for dose escalation
    - 23.9% urethral sparing on average ($n = 26$) for boost therapy
  - Uses an FDA-approved $^{169}$Yb radiation source and afterloader
  - Delivery times reasonable with fresh sources – under 50 minutes for monotherapy, under 30 minutes for boost therapy
Future Research Directions

- Optimize to use multiple shield openings to minimize treatment time.
- RSBT treatment planning while considering delivery uncertainty
- AI for RSBT treatment planning
- Implement a prototype for cervical cancer RSBT
Grant Advice for AAPM Members

- My suggestions focus more on translational research – improving outcome of a specific patient group for a specific treatment modality.
- Clinical relevance of the project is critical.
- Strive to apply fundamental engineering solutions to a clinical problem for project innovation.
- Put less weights on conceptual novelty and “advancing a field”
- Research plan is built on preliminary data with thoughtful experimental design
- It’s easy to ignore to include an expertise of statistics in research team.
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- Yulong Liu (ECE)
- Hossein Dadkhah (BME)
- Jirong Yi, B.S. (ECE)
- Anh Le, Ph.D. (ECE)
- Quentin Adams, M.D. (Rad Onc)
- Karolyn Hopfensperger, B.S. (BME)

**Engineers**
- Kaustubh Patwardhan, M.S.
- Bounnak Thammavong, M.A.

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Thank You!

Questions?