The Radiation Planning Assistant (RPA) for Radiation Therapy Planning in Low and Middle-Income Countries

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Disclosures

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• Additional technical support + equipment from Varian Medical Systems and Mobius Medical Systems
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MD Anderson Cancer Center, Houston
- Laurence Court, PhD
- Beth Beadle, MD/PhD – head/neck
- Joy Zhang, PhD – algorithms and integration
- Rachel McCarroll – H&N algorithms
- Kelly Kisling, MS – GYN, breast algorithms
- Jinzhong Yang, PhD - atlas segmentation
- Peter Balter, PhD – radiation physics
- Ryan Williamson, MS – software tools
- David Followill, PhD – audits/deployment
- James Kanke and dosimetry team
- Danna Fullen RTT
- Ann Klopp, MD/PhD – GYN planning
- Anuja Jhingram, MD – GYN planning
- Simona Shaitemman, MD – breast

Commercial Partners
- Varian Medical Systems
- Mobius Medical Systems

Primary Global Partners
- Stellenbosch University, Cape Town
  - Hannah Simonds, MD
  - Monique Du Toit – physics
  - Chris Trauernicht - physics
  - Vikash Sewram, PhD
- Santo Tomas University, Manila
  - Michael Mejia, MD
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  - Teresa Sy Ortin, MD

Global testing sites
- University of Cape Town
  - Hester Berger, PhD
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- University of the Free State
  - William Rae, PhD
  - William Shaw, PhD
  - Alicia Sherriff, MD
- Additional centers
Motivation

• There aren’t enough physicists
  • Approximately 50% of physicist time is spent doing treatment planning
• Optimized dose distributions can reduce patient toxicity

Comparison of the dose distribution for a chest wall treatment with optimized wedges (right) and with open fields (left). The non-optimized plan has a large region of soft tissue receiving 60Gy (6000cGy), compared with 52Gy (5200cGy) in the optimized plan.
Radiation Planning Assistant

**Primary Planning**
- CT Table Removal
- Body Contour Definition
- Marked Isocenter Detection
- Atlas-Based Contouring
- Create fields
- Optimize dose
- Calculate dose

**Secondary Verification**
- CT Table Removal
- Body Contour Definition
- Marked Isocenter Detection
- Atlas-Based Contouring
- Create fields
- Optimize dose
- Calculate dose

Do primary and secondary methods agree?

- Yes
- No

Plan Documentation

MD approves plan?

- Yes
- No

Manual planning

Transfer Plan to Record and Verify

Key
- Radiation oncologist
- Medical physicist
- Technologist

MD treatment planning order

CT or 2D simulation

Primary dose: Eclipse
Secondary dose: Mobius

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Specific goals of the Radiotherapy Planning Assistant (RPA)

• Automatically create high quality radiation plans for cancers of the:
  • Cervix
  • Breast (intact and chest wall)
  • Head and neck (nasopharynx, oropharynx, oral cavity, larynx, etc.)

• Generate treatment plans that are:
  • Generated from scratch (including transfer to the local machine) in less than 30 minutes.
  • Compatible with all treatment units and record-and-verify systems.
  • Internally QA’d in an automated fashion within the system.

• Limit need for the radiation oncology physician to:
  • Delineate the target (location).
  • Provide the radiation prescription.
  • Approve the final plan.

• Create a system that can be used by an individual with:
  • A high school education.
  • ½ day of training (online and video) on the RPA itself.
General philosophy

• Take advantage of Eclipse, but avoid the need for the user to actually use Eclipse
• Use Eclipse functions whenever possible (API)
• Combine with purpose-written tools
• Internal verification for everything
• Work closely with eventual users
• Deploy locally or at central hub
  • Eventually this could/should be cloud based
• Specifically designed documentation
Feedback and development

Extensive and continual clinical feedback is a key factor in this project

- Feedback and interaction with radiation oncologists at MD Anderson, South Africa and the Philippines
  - Continual feedback from MDACC radiation oncologists
  - Monthly feedback from primary partners (South Africa and the Philippines)
  - Specific feedback from wider partners

- Clinical deployment at Anderson
  - Head/neck normal tissue autocontouring deployed at MD Anderson since 2016, ~250 patients so far
  - Cervical cancer field apertures deployed at MD Anderson since June 2016, 22 patients so far

- Full clinical deployment at LMIC partners (next year)
Current status: Cervical cancer treatment plans

- Fully automated plans working, including apertures, dose calculation, field weight optimisation
- Acceptable 4-field box plans ~21 minutes
- Tested on total 400+ unique patients
- Reviewed by physicians from MD Anderson (USA) and Stellenbosch University (South Africa)
- Most recent version
  - $n = 150$
  - 89% Approval Rate
  - #1 cause of rejection: superior border
    - **Otherwise, 99% of plans are acceptable**
- Aperture creation deployed to MD Anderson clinic
- Verification: 2 methods – (1) 2D registration, (2) deep-learning

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## Iterations of testing

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Patients</th>
<th>Reviewed By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 2016</td>
<td>Initial Test (v1)</td>
<td>n = 39</td>
<td>MDA physician</td>
</tr>
<tr>
<td>Jun 2016</td>
<td>MD Anderson clinical implementation (vMDA.1)</td>
<td>n = 18</td>
<td>Physician edits</td>
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<tr>
<td>Dec 2016</td>
<td>2nd physician review of initial test (v1)</td>
<td>n = 39</td>
<td>Tygerberg physician</td>
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<tr>
<td>Jan 2017</td>
<td>Test on 1st set of Stellenbosch patients (v2)</td>
<td>n = 9</td>
<td>Clinical target contours</td>
</tr>
<tr>
<td>Jan-Feb 2017</td>
<td>1st large test of full automation (v3)</td>
<td>n = 228</td>
<td>MDA physician</td>
</tr>
<tr>
<td>Mar 2017</td>
<td>2nd large test of full automation (v4)</td>
<td>n = 150</td>
<td>MDA and Tygerberg physicians</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>Test on 2nd set of Stellenbosch patients (v4)</td>
<td>n = 8</td>
<td>Clinical target contours</td>
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<td>May 2017</td>
<td>MD Anderson clinical implementation (vMDA.2)</td>
<td>n = 3</td>
<td>Physician edits</td>
</tr>
<tr>
<td>Sep 2017</td>
<td>Onsite test - South Africa (v5)</td>
<td>n = 23</td>
<td>Groote Schuur and Tygerberg physicians</td>
</tr>
</tbody>
</table>

Tested on 469 unique patients!
Head and neck planning

Time for IMRT planning for a complex case (excluding contouring)

N=167, ASTRO 2004
Current status: Head / neck VMAT plans

- We now have clinically acceptable single-shot plans (~45 minutes)
- Radiation Oncologist delineates the GTV – everything else is automated
  - Nodal level contouring
  - Normal tissue contouring
  - Plan optimization
  - Internal QA
  - Multi-atlas contouring (in-house)

- Normal tissue contouring deployed at MD Anderson (250+ patients)
- 100% of plans have been approved by rad oncs (small n)
- Machine learning tool for predicting contour quality –effective at detecting contouring errors

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ROC - Simulated Errors

- Brain
- BrainStem
- Cochlea
- Eye
- Lung
- Mandible
- Parotid
- Spinal

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Validation of Autoplanning

• RTOG 0522 - A Randomized Phase III Trial of Concurrent Accelerated Radiation and Cisplatin versus Concurrent Accelerated Radiation, Cisplatin, and Cetuximab (C225) [Followed by Surgery for Selected Patients] for Stage III and IV Head and Neck Carcinomas
  • Only IMRT patients chosen for this analysis (19 patients so far)
  • $PTV_{\text{HighDose}}$: $35 \times 2\text{Gy}=70\text{Gy}$
  • $PTV_{\text{ElectiveDose}}$: $35 \times 1.6=56\text{Gy}$

• MDACC clinical cases
  • 30 patient, mixed stage head and neck carcinomas
  • VMAT cases chosen for this analysis (30 patients)
Validation of Autoplanning - Results

a. Comparison with RTOG0522

b. Comparison with MDACC clinical cases

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Validation of Autoplanning - Results

a. Comparison with RTOG0522

b. Comparison with MDACC clinical cases
Validation of Autoplanning - Results
Feedback at the International Conference on Advances in Radiation Oncology (ICARO2), IAEA, 20-23 June 2017

- Participants were mostly European
- Head/neck (3 plans on slides):
  - Wide acceptance of head/neck VMAT (76% of people with appropriate equipment)
- Cervix (2 plans on slides):
  - 25% approval for 4-field box approach
  - The majority of participants use 3D conformal, IMRT or VMAT treatments

RPA impact question (head/neck cancer): Based on these examples, would you use RPA for planning head/neck treatments?

A. Yes 67%
B. I would like to, but do not have the right equipment (CT scanner, VMAT-capable LINAC) 21%
C. No - the plans do not have sufficient quality 13%
D. No – other reason 0%

RPA impact question (cervical cancer): Based on these examples, would you use RPA for planning cervical cancer treatments?

A. Yes 25%
B. I would like to, but we do not have the appropriate equipment (CT or MLCs) 4%
C. No – we base our treatments on contoured targets and normal tissues 64%
D. No – there is no benefit for us 4%
E. No – other reason 4%
South African Partners

University of the Free State

Groote Schuur Hospital, University of Cape Town

Tygerberg Hospital, University of Stellenbosch

Limpopo

Windhoek

Gaborone

East London
South Africa data trip, September 2017

• Laurence Court, Kelly Kisling and Rachel McCarroll visited SA for a week
• 3 days at Tygerberg and 2 days at Groote Schuur
• Collected patient data for planning

Tygerberg Hospital, Stellenbosch University

• Cervical cancer treatments
  • Collected 33 patient CTs
  • Ran 10 cervical cancer patients through the RPA and reviewed with Dr. Simonds (~1 hour)
    • She approved all 10 plans

• Head/neck treatments
  • Collected 22 patient CTs
  • Ran 5 H/N patients through the RPA and reviewed with Dr. Naidoo
  • Spent ~90 minutes carefully reviewing these 5 RPA plans
  • She approved all plans – sees advantage in coverage and normal tissue dose
South Africa data trip, September 2017

Groote Schuur Hospital, University of Cape Town

- **Cervical cancer treatments**
  - Collected 13 patient CTs
  - Ran 13 cervical cancer patients through the RPA and reviewed 4 with Dr Fakie (+2 residents) ~1 hour
    - She approved all 4 plans
    - The resident (Kenyan) said they are typical of the plans used in Kenyan clinics

- **Head/neck treatments**
  - Collected 10 patient CTs
  - Reviewed 3 Tygerberg patient RPA plans with Dr. Wetter
  - Spent ~2½ hours carefully reviewing these RPA plans
  - She approved all plans
    - “would treat this plan as is”
    - “can’t complain at all”
    - “no way to find fault”
Summary of current status of the RPA project

☑ Fully automated head/neck plans
☑ Fully automated cervical cancer plans
☒ Finalizing integration with Eclipse and larger scale, formal testing/feedback
☒ Chestwall – Goal is to complete by year-end

☒ Enter Clinical Evaluation phase in May 2018
  • (if funding is confirmed)
  • First deploy at Tygerberg, Groote Schuur and Santo Tomas
  • Then add Bloemfontein
  • Then East London, Limpopo, others..... (TBD)
In the context of this workshop

• Automated treatment planning is essential
• Automated treatment planning is possible
• Continual feedback from eventual users is vital
• Additional software QA is also important
Treatment chairs:

- Have clinical support
- Can be clinically beneficial
- Have a long (mostly forgotten) history