Automation in Therapy: The Future is Now

Automated treatment planning

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Conflicts of Interest

• Funded by NCI UH2 CA202665
• Equipment and technical support provided by:
  • Varian Medical Systems
  • Mobius Medical Systems
• Other, not related projects funded by NCI, CPRIT, Varian, Elekta

• MD Anderson Cancer Center-Houston
  • Laurence Cour, PhD
  • Joy Zhang, PhD – algorithms and integration
  • Rachel McCarroll – SBH algorithms
  • Kelly Kilian, MS – GYN, breast algorithms
  • Joseph Yang, PhD – atlas segmentation
  • Peter Bakke, PhD – radiation physics
  • Ryan Williamson, MS – software tool
  • Ann Klop, MD/PhD – GYN planning
  • Ana Kingma, MD – GYN planning
  • Simona Shatremian, MD – breast
  • David Fokasell, PhD – audits/deployment
  • James Karle and dosimetry team

Stanford
  • Beth Beadle, MD/PhD – head/neck

Commercial Partners
  • Varian Medical Systems
  • Mobius Medical Systems

Primary Global Partners
  • Stellenbosch University, Cape Town
    – Hannah Simonds, MD
    – Montique Du Toit – physics
    – Chris Trautvetter - physics
    – Vikash Seerar, PhD
  • University of Cape Town
    – Hester Berger, PhD
    – David Anderson, MD
    – Jeannette Verkes, MD
  • Santo Tomas University, Manila
    – Michael Mejia, MD
    – Maureen Bajador, MS (physics)
    – Teresa Sy Ortin, MD

Global testing sites
  • University of the Free State
    – William Shaw, PhD
    – Abiba Sherriff, MD
Cancer across the world

- Low and Middle Income Countries (LMIC)
  - Population: 5.625 billion (84%)
  - Global Burden of Disease (GBD)
    - 28.4% Communicable diseases
    - 71.6% Non-communicable diseases
    - 16% of global cancer mortality
    - 15% of radiation facilities
- Affordable Cancer Technologies (NCT) projects
  - Phase 1 (UH2): Development Phase – 2 years – to April 2018
    - System development at MDACC, initial testing at partner sites
  - Phase 2 (UH3): Validation Phase – 3 years
    - Full patient testing

Motivation for automated planning 1: Staff shortages

<table>
<thead>
<tr>
<th>Country</th>
<th>Treatment units</th>
<th>Radiation oncologists</th>
<th>Medical physicists</th>
<th>Radiation therapy technologists</th>
</tr>
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<tr>
<td>Philippines</td>
<td>140</td>
<td>141</td>
<td>133</td>
<td>382</td>
</tr>
<tr>
<td>South Africa</td>
<td>50</td>
<td>93</td>
<td>82</td>
<td>82</td>
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<tr>
<td>All LMIC regions</td>
<td>9569</td>
<td>12,147</td>
<td>9,915</td>
<td>29,140</td>
</tr>
</tbody>
</table>

- Large deficit in resources – including medical physicists and technologists
- Staff retention is also a problem (anecdotal)
- Many international guidelines suggest that medical physicists need 2+ years residency, typically following graduate school – so 4+ years per person.
- Approximately 50% of physicist time is spent doing treatment planning
- If planning was automated, then the deficit of medical physicists could be reduced to ~5000.

Motivation 2: 3D planning

- All our partner institutions are treating chest walls using standard opposed oblique open fields (i.e. not optimized for the individual patient’s geometry)
- Automated planning could change this

Companion 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.

IAEA: The Advisory Group on increasing access to Radiotherapy Technology [AGaRT] in low and middle income countries.

Samiei, Massoud.. Challenges of making radiotherapy accessible in developing countries. Cancer Control 2013: 85.

Atun et al, Expanding global access to radiotherapy, Lancet Oncol 16, 1153-86, 2015

Motivation 3: Consistency

- Head and neck (H&N) tumors are typically surrounded by a large number of OARs
- CTV delineation a particularly difficult and time consuming task
- Several reports of high inter-observer variability
- Automating this process:
  - Reduced contouring time
  - Potentially reduce contouring variability

Specific goals of the Radiotherapy Planning Assistant (RPA)

- Automatically create high quality radiation plans for cancers of the:
  - Uterine Cervix
  - Breast (intact and chest wall)
  - Head and neck (nasopharynx, oropharynx, oral cavity, larynx, etc.)
- Generate treatment plans that:
  - 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.
  - (Dosimetrist still needed for unusual/complex cases)

A comment about Treatment Planning Systems

- Our experience is based on the Eclipse TPS
- Similar automation tasks can be achieved with other TPS – and I will try to highlight some of these
- Several (TPS agnostic) tools have been deployed into our clinic (Pinnacle and Raystation)
Primary dose: Eclipse  
Secondary dose: Mekita  

- Do primary and secondary methods agree? 
  - No  
  - Yes

Plan Documentation

- MD approves plan?
  - Yes  
  - No

Transfer Plan to Record and Verify

- Manual planning
  - Yes  
  - No

Eclipse Scripting API

- Plugin Script
  - Eclipse calls you!
  - Operates on current patient

- Standalone EXE
  - You call Eclipse!
  - Operates on any number of patients

ARIA DB

Slide from Wayne Keranen, Varian
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 (extensive use of DICOM)
- Internal verification for everything
- Work closely with eventual users
- Deploy at MDACC whenever possible

**Version 3 Architecture**

**Pre-processing**
CT Table Removal

Method 1: Peak Detection
By finding peaks slice by slice at sum projection signal along lateral direction.

Method 2: Line Detection
By detecting Hough lines at maximum intensity projection image.

• Average difference between two approaches: 2.6 ± 1.6 mm (max: 4.9 mm)

Body Contour

Method 1: Active Contour
By contracting initial active contour to the body edge.

Method 2: Intensity Thresholding
By thresholding CT image into binary mask.

• Average agreement = 0.6 mm, Average max: 7.6 mm

[paperwork design to improve efficiency of plan checks]
Marked Isocenter Detection

Method 1: Body Ring Method
By searching BB candidates in the body ring domain.

Method 2: BB Topology Method
By searching BBs that constitute the triangle topology.

• Average difference between two approaches: 0.4 ± 0.8mm (max: 3.0mm)

Cervix

For cervical cancer treatment:
Determine the jaws and blocks

1st Algorithm
"3D Method"
Input: Patient CT and isocenter
Inter-compare
Output: Treatment fields

2nd Algorithm
"2D method" + Registration approach + Deep learning approach
Input: Patient CT and isocenter
Inter-compare
Output: Treatment fields
Create Treatment Beams (3D method)

**INPUT:** Patient CT and isocenter

**OUTPUT:** 4 treatment fields

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**Iterations of testing**

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>n</th>
<th>Reviewer</th>
</tr>
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<tbody>
<tr>
<td>Feb 2016</td>
<td>Initial test (v1)</td>
<td>39</td>
<td>Reviewed by MD Anderson</td>
</tr>
<tr>
<td>Jan 2016</td>
<td>More accurate clinical implementation (ANRA.1)</td>
<td>39</td>
<td>Reviewed by MD Anderson</td>
</tr>
<tr>
<td>Dec 2016</td>
<td>End of physician review of Initial test (v1)</td>
<td>39</td>
<td>Reviewed by Tygerberg physician</td>
</tr>
<tr>
<td>Jan 2017</td>
<td>Test on 1st set of Malmesbury patients (v2)</td>
<td>18</td>
<td>Reviewed by MD Anderson</td>
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<tr>
<td>Feb 2017</td>
<td>3D large test of full automation (v2)</td>
<td>228</td>
<td>Reviewed by MD Anderson</td>
</tr>
<tr>
<td>Mar 2017</td>
<td>Radiation test of full automation (v2)</td>
<td>39</td>
<td>Reviewed by MD Anderson</td>
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<tr>
<td>Apr 2017</td>
<td>Test of 4th set of Malmesbury patients (v4)</td>
<td>8</td>
<td>Reviewed by Tygerberg physician</td>
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<tr>
<td>May 2017</td>
<td>More accurate clinical implementation (ANRA.2)</td>
<td>150</td>
<td>Reviewed by MD Anderson</td>
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<tr>
<td>Sep 2017</td>
<td>Onsite test - South Africa (v5)</td>
<td>23</td>
<td>Reviewed by Groote Schuur and Tygerberg physicians</td>
</tr>
</tbody>
</table>

Test on 469 unique patients!

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**Optimized beam weights**

- Compared dose distributions using optimized beam weights to equal beam weights
  - n = 149
    - Wilcoxon signed-rank test
    - Reduced maximum dose
    - Median change: -1.0%
    - p < 0.001
    - Range: -10.0% to +0.4%
    - Coverage maintained
      - % volume covered by 95% of Rx
      - Median change: -0.5%
      - p < 0.001
      - Range: 2.0% to +2.8%

- Increased Max Dose
- Decreased Max Dose
Greatest effect for hotter doses

- Looking at patients with higher maximum doses
  - >= 107% of Rx
- Reduced maximum dose
  - Hottest 1cc
  - Median change: -3.5%
- Percent of patients
  - Equal weights: 44%
  - Optimized weights: 3%

The Big Test

- Retrospective
- MDACC patients (n=150)
- Radiation Oncologist rates fields as acceptable for treatment or not (pass/fail)
  - Target pass rate is 95%
  - 2 Radiation Oncologists (MDACC and Stellenbosch U)
- Pass rate
  - 89% of patients
  - (round 1 = 78%)
- #1 cause of rejection: superior border
  - Otherwise, 99% of plans are acceptable

Clinical Version Deployed at MD Anderson

- Auto-planned fields after physician edits
  - 24 patients so far
  - ~10 minutes per patient
Deep Learning Solution?

**Input**: Patient CT and Isocenter

**Digitally Reconstructed Radiograph**

**Beam Aperture**

Cervical Cancer Beam Aperture

- **Convolutional Neural Networks**
  - Local connectivity
  - Provides spatial context
  - Shift invariant
- **Great for**
  - Image segmentation
    - VGG-16, U-Net, etc.
  - Image classification
    - AlexNet, VGG, etc.
- **CNNs have become very popular in medical imaging research**

Deep Learning Approach

- We chose two image segmentation architectures
  - VGG19
  - U-Net
- **Comparison between results**
Test Set Results
Patient #1 – “Worst” case

Cervical cancer 4-field box plans - summary

- Automatic generation of field apertures – used in our clinic
- Automatic beam-weight optimisation
- Secondary calculations to check quality
- Currently a complete plan takes ~20 minutes

Head and neck
Head and neck treatments

- Range of complexities in treatments
  - VMAT or IMRT
  - Opposed laterals / off-cord cone-downs
  - Complex conformal plans
- Starting with VMAT (IMRT)
  - Auto-contouring normal tissue
  - Auto-contouring low-risk CTV
  - Manual contouring of GTV
  - RapidPlan (Eclipse)

Workflow overview (user’s perspective)

1. Add GTV
2. Review/edit contours

Normal tissue contouring
The search for a good contouring algorithm

Eight contouring algorithms options evaluated:
1. Eclipse Smart Detection (Heuristic)
2. Eclipse Smart Segmentation (DIR)
   a) Single Atlas
   b) Fused Atlas
3. Varian Deeds (DIR)
   a) Varian Atlas
   b) Two-fusion techniques:
      • Majority voting
      • STAPLE fusion
   b) MDACC Atlas
4. In-house multi-atlas technique – MACS (DIR) (STAPLE fusion)
   a) MDACC Atlas
   b) Original Varian Atlas

Case #3: Normal Tissue Autocontouring

Results – Physician Review

Of the 5 autocontouring techniques, the in-house “MACS” system was best performing.
In-house and commercial solution (RayStation) vs. manual contours

<table>
<thead>
<tr>
<th>Structures</th>
<th>Commercial solution</th>
<th>In-house solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dice</td>
<td>MDE (mm)</td>
</tr>
<tr>
<td>Brain</td>
<td>0.99±0.09</td>
<td>0.86±0.3</td>
</tr>
<tr>
<td>Brainstem</td>
<td>0.84±0.04</td>
<td>0.3±0.3</td>
</tr>
<tr>
<td>Spinal Cord</td>
<td>0.85±0.02</td>
<td>1.3±0.8</td>
</tr>
<tr>
<td>Parotid</td>
<td>0.81±0.05</td>
<td>2.2±0.6</td>
</tr>
<tr>
<td>Mandible</td>
<td>0.96±0.03</td>
<td>0.9±1.3</td>
</tr>
<tr>
<td>Cochlea</td>
<td>0.78±0.05</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>Eyes</td>
<td>0.89±0.04</td>
<td>1.3±0.8</td>
</tr>
<tr>
<td>Lungs</td>
<td>0.87±0.31</td>
<td>3.8±1.2</td>
</tr>
</tbody>
</table>

Data from Jinzhong Yang and Peter Balter (submitted to ASTRO 2018)

Clinical use of OAR autocontouring

Analysis of 228 patients (18 months)

Possible use of margins to account for contouring uncertainties

Dosimetric impact of OAR autocontouring

- 54 patients with clinically edited autocontours
- Use (1) unedited original and (2) edited contours for planning
- Evaluate the plan on physician edited "true" structures
Results – Dosimetric impact of OAR

Target contouring

Case #3: Target Volume Autocontouring
Results – Primary Physician Review (n=115)

Results – International Review (5 physicians, n=10)

Deep learning for contour QA?

- Secondary technique
  - Two channel U-Net architecture (3D variant)
  - Trained on 210 bilateral oropharynx patients
  - Requires CT, GTV contour(s), external contour
  - Tested on 85 independent cases: Dice 0.78±0.05
Results – Assessment of autocontour quality

"Disagreement" with secondary check is correlated to disagreement with physician CTVs

Plan optimization
Plan automation has been demonstrated to save time:

**Fully Automated Volumetric Modulated Arc Therapy Plan Generation for Prostate Cancer Patients**

Peter W.J. Voel, R.T.R., Maarten L.P. Dirkx, PhD; Sebastiaan Broederval, PhD; Arif H. A. Hamoud, MD, PhD; Luca D’Hondt, MD, PhD; and Ben J.H. Heijmen, PhD

Department of Radiation Therapy, Erasmus MC, University Medical Center Rotterdam, Rotterdam, the Netherlands

- Purpose – single-run optimization, avoiding manual tweaking
- Commercial TPS linked to in-house optimizer for pre-optimization
- Demonstrated fully automated VMAT planning for prostate plans
- Plans were clinically acceptable – and saved 1+ hours of hands on time

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**Methods – Single optimization treatment plans**

- **Planning approach**
  - Physician drawn targets and OARs
  - Supplement with autocontoured structures
  - Missing normal structures
  - Various planning structures
  - Isocenter at target center
  - Collimator size/angle based on targets
    - 30° and 330° collimator angles, symmetric fields, 18cm max
    - 90° collimator angle, split field if superior-inferior dimension exceeds 18cm
  - WUSTL Rapid Plan Model + Population Constraints
  - Normalize such that all PTVs receive ≥98% of prescribed dose to 95% volume

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**Use Eclipse RapidPlan to predict DVHs**
And optimization constraints

- Pinnacle Auto-Planning module
- Created clinically acceptable treatment plans in 26/26 cases

Results – Single Optimization Approach
## Results – Clinical vs RPA plans

<table>
<thead>
<tr>
<th>Location</th>
<th>RPA Mean</th>
<th>RPA SD</th>
<th>Clinical Mean</th>
<th>Clinical SD</th>
<th>% Meeting</th>
<th>RPA better</th>
<th>Clinical better</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spinal Cord</strong></td>
<td>0.00</td>
<td>0.17</td>
<td>0.17</td>
<td>0.02</td>
<td>1.00</td>
<td>99%</td>
<td>100%</td>
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<tr>
<td><strong>V_45Gy</strong></td>
<td>0.63</td>
<td>0.25</td>
<td>1.00</td>
<td>0.70</td>
<td>95%</td>
<td>95%</td>
<td>100%</td>
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<tr>
<td><strong>Brainstem</strong></td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>100%</td>
<td>99%</td>
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<tr>
<td><strong>V_50Gy</strong></td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
</tr>
<tr>
<td><strong>Ipsilateral Parotid</strong></td>
<td>0.00</td>
<td>0.10</td>
<td>0.00</td>
<td>0.00</td>
<td>56%</td>
<td>50%</td>
<td>56%</td>
</tr>
<tr>
<td><strong>V_30Gy</strong></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
</tr>
<tr>
<td><strong>Contralateral Parotid</strong></td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.76</td>
<td>88%</td>
<td>86%</td>
<td>88%</td>
</tr>
<tr>
<td><strong>V_30Gy</strong></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>56%</td>
<td>50%</td>
<td>56%</td>
</tr>
<tr>
<td><strong>Ipsilateral SMG</strong></td>
<td>0.00</td>
<td>0.31</td>
<td>0.01</td>
<td>25%</td>
<td>10%</td>
<td>25%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Contralateral SMG</strong></td>
<td>0.00</td>
<td>0.81</td>
<td>0.00</td>
<td>46%</td>
<td>32%</td>
<td>46%</td>
<td>32%</td>
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<tr>
<td><strong>Cochleae</strong></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>86%</td>
<td>93%</td>
<td>93%</td>
</tr>
<tr>
<td><strong>V_35Gy</strong></td>
<td>0.01</td>
<td>0.25</td>
<td>0.00</td>
<td>93%</td>
<td>86%</td>
<td>93%</td>
<td>86%</td>
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<tr>
<td><strong>Optic Chiasm</strong></td>
<td>0.02</td>
<td>0.75</td>
<td>0.03</td>
<td>100%</td>
<td>95%</td>
<td>100%</td>
<td>95%</td>
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<tr>
<td><strong>Optic Nerves</strong></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>96%</td>
<td>90%</td>
<td>96%</td>
<td>90%</td>
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<tr>
<td><strong>Lens</strong></td>
<td>0.00</td>
<td>0.13</td>
<td>0.00</td>
<td>88%</td>
<td>82%</td>
<td>88%</td>
<td>82%</td>
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<tr>
<td><strong>High Dose PTV V_1cc</strong></td>
<td>0.00</td>
<td>0.22</td>
<td>0.00</td>
<td>100%</td>
<td>99%</td>
<td>100%</td>
<td>99%</td>
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<tr>
<td><strong>High Dose PTV V_95%</strong></td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>97%</td>
<td>97%</td>
<td>97%</td>
<td>97%</td>
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<tr>
<td><strong>Intermediate Dose PTV V_95%</strong></td>
<td>0.00</td>
<td>0.26</td>
<td>0.00</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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<tr>
<td><strong>Low Dose PTV V_95%</strong></td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

RPA plans are better Clinical plans are better

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## Head and neck automated planning summary

- Automated contouring of normal tissues – deployed into clinic
- Automated contouring of targets – works (not deployed)
- Automated VMAT plans
- Currently, the entire automated process takes ~40 minutes

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## Breast
Automated breast planning

- Purdie: Princess Margaret approach
- Wire placed around the breast tissue or along chest wall
- Markers used to denote margins (4)
- Heuristic optimization to place beams (based on lung, heart contours)
- Originally integrated into Pinnacle. Now available in RayStation

Zhao et al: Support vector machine algorithm to determine beam placement


Chest wall – works-in-progress

- Autocontour chest wall, lung, heart, SCV, humeral head, spinal canal, trachea and cricoid
- SVM for gantry, collimator angles, and medial border for SCV field (tangents first, then SCV)
- BEV of cricoid and humeral head for rest
- Field-in-field apertures/weight optimization

Physician feedback
Primary Partners

Data gathering trips, 9/2017, 1/2018, 3/2018

Santo Tomas University, Manila
  • Head/neck treatments
  • Reviewed 20 patient RPA plans with radiation oncologist
  • They approved all plans
  • Ran 3 patients through RPA, and reviewed – approved
  • Plans for which V105 > 8% are flagged to the user

Tigerberg Hospital, Stellenbosch University
  • Cervical cancer treatments
  • Ran 10 cervical cancer patients through the RPA and reviewed with rad onc (~1 hour)
  • She approved all 10 plans
  • Head/neck treatments
  • Ran 5 + 3 H/N patients through the RPA and reviewed with radiation oncologist
  • She approved all plans

Groote Schuur Hospital, University of Cape Town
  • Cervical cancer treatments
  • Ran 13 cervical cancer patients through the RPA and reviewed 4 rad onc ~1 hour
  • She approved all 4 plans
  • Head/neck treatments
  • Reviewed 3 patient RPA plans with radiation oncologist
  • They approved all plans

Quality Assurance
Quality Assurance

- Basic QA of input data
- Dose the site match?
- L/H vs. pelvis
- Is the orientation correct?
- CT scan length sufficient?
- Comparison of primary and secondary algorithms
  - Dose calculation: Eclipse vs. Mobius
  - Other independent algorithms for all other functions
    - Couch removal
    - Contours
    - Beam apertures

Simple image registration

Quality Assurance

- Comparison with population values
  - MU
  - Jaw positions
- Data transfer checks (automatic)
- Manual plan checks
  - Planning technician
  - Physics
  - Radiation oncology

Jaw positions – population statistics

<table>
<thead>
<tr>
<th>jaw/phi</th>
<th>x</th>
<th>y</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>16.4</td>
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<tr>
<td></td>
<td>St. dev.</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>15.7</td>
</tr>
<tr>
<td></td>
<td>max</td>
<td>18.2</td>
</tr>
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</table>

Total MU – population statistics

<p>| | |</p>
<table>
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</thead>
<tbody>
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</tr>
<tr>
<td>St. dev.</td>
<td>9</td>
</tr>
<tr>
<td>min</td>
<td>200</td>
</tr>
<tr>
<td>max</td>
<td>220</td>
</tr>
</tbody>
</table>
Initial technical review

• Double check of vital plan check functions
• Only get to this point if passes all internal QA checks
• Technical items checked:
  – Marked isocenter
  – Patient orientation, laterality and site
  – Body contour
  – CT processing (couch removal)
  – Field apertures
  – Any significant artifacts or differences
• Purpose designed document to lead the user through the checks

Marked isocenter

Checklist

☐ Yes ☐ No: Are all 3 fiducials visible on at least one of the slices shown?
☐ Yes ☐ No: Do the central axis lines touch each fiducial on at least one slice?

Patient results

Library examples

Body contour

Checklist

☐ Yes ☐ No: On the CT slices, is the body correctly contoured (e.g. not including the couch)?
☐ Yes ☐ No: Is the body contour smooth, like the library case?
☐ Yes ☐ No: Is the orientation consistent with the library case?
Field apertures

Checklist:
- Yes  No: Is the patient orientation and body part consistent with the reference case
- Yes  No: Are the blocks/MLCs in the acceptable region?
- Yes  No: Are there any significant differences between the patient and library images?

Completeness of dose calculation

How well can the planning technologist evaluate plans?

- Total 7 pages, 23 questions
- Training video (for technical plan checks)
- 4 physics undergraduates, 16 patient plans with intentional errors
- Time taken to check each plan: Average 8 min?

<table>
<thead>
<tr>
<th>Correctly identified errors</th>
<th>Marked isocenter</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body contour</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Field apertures</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Differences in images (including orientation)</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Unanticipated error type (missing field)</td>
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</tbody>
</table>

Court et al. Radiation Planning Assistant - A streamlined, fully automated radiotherapy treatment planning system, Jove 2018 (accepted)
Automation of treatment planning: Summary

- Automatic treatment planning may help reduce the planning burden, reducing staff shortages
- Fully automated cervical cancer 4-field box treatments – done (20 min per plan)
  - Field aperture task already at MDA
- Fully automated H/N IMRT/VMAT treatment planning – mostly done (40 min per plan)
  - Normal tissue contouring task deployed at MDA
- Breast/chest wall – next
- Start deploying (if funded) late 2018.