Clinical Experience with Automated Multicriteria Optimization
Ben Heijmen, Sebastiaan Breedveld

Joint AAPM-ESTRO Symposium: Automated Treatment Planning in Clinical Practice
AAPM 2018, Nashville

Disclosures

Erasmus MC Cancer Institute has research agreements with Elekta AB (Stockholm, Sweden) and Accuray Inc (Sunnyvale, USA).

Elekta AB is preparing commercialization of the Erasmus-iCycle approach for automated multi-objective planning.

Clinical Experience with Automated Multicriteria Optimization

Outline
- Erasmus-iCycle
- Validation of automatic planning: comparison with manual
- Reduction of bias and enhancement of patient numbers in planning studies for treatment technique comparisons
- Challenges and Future
**Erasmus-iCycle**

Fully automated, multi-criterial optimization (MCO)

- **a posteriori MCO**: user selects final, clinically favourable plan
- **a priori MCO**: system automatically selects the final, clinically favourable plan on Pareto front

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**Craft et al.**

- **a posteriori MCO**: user selects final, clinically favourable plan


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**Constraints**

<table>
<thead>
<tr>
<th>Volume</th>
<th>Type</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV</td>
<td>Max dose</td>
<td>105% of DPx</td>
</tr>
<tr>
<td>PTV</td>
<td>Mean dose</td>
<td>101% of DPx</td>
</tr>
<tr>
<td>Rectum &amp; Anus</td>
<td>Max dose</td>
<td>102% of DPx</td>
</tr>
<tr>
<td>PTV Shell 50mm</td>
<td>Max dose</td>
<td>50% of DPx</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Max dose</td>
<td>105% of DPx</td>
</tr>
</tbody>
</table>

**Objectives**

<table>
<thead>
<tr>
<th>Priority Volume</th>
<th>Type</th>
<th>Goal</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PTV</td>
<td>(LTOP)</td>
<td>0.8</td>
<td>( D_{0, \gamma} = 78 \text{ Gy} ), ( \alpha = 0.8 )</td>
</tr>
<tr>
<td>2 Rectum</td>
<td>(EUD)</td>
<td>30 Gy</td>
<td>( k \approx 12 )</td>
</tr>
<tr>
<td>3 Rectum</td>
<td>(EUD)</td>
<td>10 Gy</td>
<td>( k \approx 8 )</td>
</tr>
<tr>
<td>4 PTV Shell 5 mm</td>
<td>Max dose</td>
<td>90% of DPx</td>
<td></td>
</tr>
<tr>
<td>Skin ring 20 mm</td>
<td>Max dose</td>
<td>20% of DPx</td>
<td></td>
</tr>
<tr>
<td>5 Rectum</td>
<td>Mean dose</td>
<td>5 Gy</td>
<td></td>
</tr>
<tr>
<td>6 Anus</td>
<td>Mean dose</td>
<td>5 Gy</td>
<td></td>
</tr>
<tr>
<td>7 Bladder</td>
<td>Mean dose</td>
<td>5 Gy</td>
<td></td>
</tr>
<tr>
<td>8 PTV Shell 15 mm</td>
<td>Max dose</td>
<td>50% of DPx</td>
<td></td>
</tr>
<tr>
<td>PTV Shell 25 mm</td>
<td>Max dose</td>
<td>35% of DPx</td>
<td></td>
</tr>
<tr>
<td>9 Left &amp; Right Femoral Heads</td>
<td>Max dose</td>
<td>50% of DPx</td>
<td></td>
</tr>
</tbody>
</table>

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**same wish-list used for all patients (no patient-specific tweaking)**
Generation of wish-lists: improve on training plans

- definition of initial wish-list based on:
  - planning protocol
  - review of recent clinical plans
  - discussions with clinicians and planners

for limited number of training patients (~5):
automated plan generation with Erasmus-iCycle
based on current wish-list

update current wish-list

YES

evaluate plans

Final wish-list = current wish-list

NO

Highlight of Erasmus-iCycle:

✓ automatically one Pareto-optimal plan, clinically favourable trade-offs, OAR doses as low as feasible
✓ no operator dependence of plan quality, consistently high
✓ huge reduction in planning workload

Highlights of Erasmus-iCycle:

✓ automated beam profile and beam angle optimization
✓ versions for IMRT/VMAT, Cyberknife and protons
  (version for BT being developed, AAPM 2018, Kolkman-Deurloo et al.)
✓ highly suited for ‘unbiased’ treatment technique comparisons; automated planning with same wish-list
Erasmus-iCycle

*Fully automated, multi-criterial optimization (MCO)*

Clinical implementation

- Tumor site specific wish-lists
- Commercial TPS:
  - ✓ Monaco (Elekta linacs)
  - ✓ Multiplan (Cyberknife)
  - Patient-specific template
  - Commercial TPS
  - Automatically generated Plan
Erasmus-iCycle is in routine clinical use for VMAT and IMRT:
➢ Head-and-neck cancer
➢ Cervical cancer (Adaptive)
➢ Prostate cancer
➢ Advanced lung cancer

(~40% of curative patients)

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Validation of automated planning based on Erasmus-iCycle

▪ Head and neck cancer
▪ Prostate and seminal vesicles
▪ Prostate and vesicles and lymph nodes
▪ Prostate SBRT with Cyberknife
▪ Gastric cancer
▪ Spinal metastases
▪ Cervical cancer
▪ Advanced lung cancer

Pubmed: Heijmen b*
**Head and Neck cancer**

*Toward Fully Automated Multicriterial Plan Generation: A Prospective Clinical Study*

Peter W.J. Voet, RTT, Maarten L.P. Dirkx, PhD, Sebastiaan Breedveld, MSc, Dennie Fransen, RTT, Peter C. Levendor, MD, PhD, and Ben J.H. Heijmen, PhD


In 97% of cases the automatic plan was selected by physician for treatment.

4 European centers
80 prostate patients (prostate + vesicles)


**AUTOplan vs. MANplan for prostate cancer**

*blinded clinician’s side-by-side plan scoring*

- **38 pts**: autoVMAT better with high impact
- **9 pts**: manVMAT better with high impact
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Issues with treatment planning studies for treatment technique comparisons

➢ Planning is manual, i.e. interactive, trial-and-error
➢ Different planning skills/experience for different treatment techniques
➢ Different TPSs for different techniques

☀ bias in treatment technique comparisons
☀ low patient numbers
Reduce bias, enhance patient numbers with Erasmus-iCycle:
✓ Fully automated planning for all techniques
✓ Same TPS, same optimization engine/schedule (wish-list) for both techniques

Prostate SBRT: VMAT vs. Cyberknife
Automatically generate 3 plans for 20 patients:
1. CK, 3 mm CTV-PTV margin (as clinical, tumor tracking)
2. VMAT, 5 mm margin (no tracking, no rotation correction)
3. VMAT, 3 mm margin (clinically not feasible)

Blinded clinician’s side-by-side plan comparisons

<table>
<thead>
<tr>
<th>CK better</th>
<th>Equal</th>
<th>VMAT better</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PTV</strong></td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Rectum</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Bladder</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Urethra</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Overall</td>
<td>11</td>
<td>8</td>
</tr>
</tbody>
</table>

Original article

VMAT plus a few computer-optimized non-coplanar IMRT beams (VMAT+) tested for liver SBRT

Abdel Wahab M. Sharif *, Maarten L.P. Dirks, Sebastiaan Breedveld, Alejandro Míñdez Romero, Ben J.M. Heijmen


15 patients
- VMAT
- VMAT+1, VMAT+2,… VMAT+5
- NCP-15, NCP-25
 liver SBRT: IGRT vs. daily adaptive re-planning

Physics Contribution
Suzanne M. Leenders, MSc.,* Sebastian Bredeld, MSc.,† Alejandro Méndez Romero, MD.,‡ Dennis Schuait, PhD.,‡ Yvette Seppenwoolde, PhD.,§ and Ben J.M. Heijmen, PhD.†
*Erasmus Medical Center-Daniel den Hoed Cancer Center, Rotterdam, The Netherlands, and †Twente University of Technology, HAN, The Netherlands
Int J Radiat Oncol Biol Phys. 2013 Dec 1;87(5):1016-21

Results

Modest impact of daily beam angle re-optimization
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Clinical implementation

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tumor site specific
wish-lists

contoured
CT-scan

Erasmus-iCycle

patient-specific
template

commercial
TPS

automatically
generated Plan
```

Erasmus-iCycle

*Fully automated, multi-criterial optimization (MCO)*

Clinical implementation

```
tumor site specific
wish-lists

contoured
CT-scan

TPS

[CE, FDA, ...]

automatically
generated Plan
```
intensive upfront time investment of doctors

≠ personnel reduction for planning
≠ no planning work

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and many (inter)national collaborators