Autoplanning in the IGRT era

Ben Heijmen

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Disclosures

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Elekta AB is preparing commercialization of the Erasmus-iCycle approach of automated multi-objective planning.
Challenge in RT:

- minimize dose in healthy tissue
- especially in important sensitive tissues (OARs)
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- minimize dose in healthy tissue
- especially in important sensitive tissues (OARs)

Action 1:

- minimize PTV margins

Action 2:

- minimize high dose outside PTV (conformality, high dose gradients)
- especially close to OARs

IMRT and VMAT with proper planning
Current ‘manual’ treatment planning:

- interactive and iterative trial-and-error procedure
- planner steers TPS towards an **acceptable plan**
  (tweaking parameters, such as cost functions or weights.)
Issues with current planning:

- Plan quality dependents strongly on
  - skills of the planner (operator dependence)
  - allotted planning time; stop when below constraints
  - subjective preferences and priorities (within the planning protocol)

- Difficult to decide when to stop; could more iterations result in a better plan?

This may compromise plan quality.

Nelms et al. Practical Radiation Oncology (2012) 2, 296–305
Berry et al. Radiotherapy and Oncology 120 (2016) 349–355
Berry et al. Practical Radiation Oncology (2016) 6, 442-449
Clinical plan

Alternative plan
(generated long time after treatment)

Electron densities are overridden on structures that may be overlapped.
Automated planning as alternative to manual planning

**Automated:**
For each patient, computer generates fully automatically ‘the’ treatment plan (PUSH-BUTTON SYSTEM)

- Ideally plan is ‘optimal’: Pareto-optimal with clinically optimal trade-offs between treatment goals

  OR

- Plan is good starting point for easy and fast improvement by manual fine-tuning.
Systems for automated planning

- Eclipse **Rapidplan** Knowledge-based planning (Varian)
- **Pinnacle Auto-Planning** (Philips)
- ‘wishlist’ based lexicographic optimization
  - **Erasmus-iCycle** (Rotterdam) + Monaco (Elekta)
  - **Raystation Plan Explorer**
  - iCycle integrated in Monaco (Elekta, not yet commercial)
- Many (in-house/heuristic) systems (for single patient group)
How good is automated planning compared to ‘manual’ planning?

Head and Neck cancer

Physics Contribution

Toward Fully Automated Multicriterial Plan Generation: A Prospective Clinical Study

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Study design

- on average 1 in 5 patients got manual and automatic IMRT plan (random patient selection)
- physician selected best plan for treatment
- dosimetrists and treating physicians didn’t know whether or not there would be an automatic plan
- all plans had coplanar beam arrangements, max 9 beams
- automated planning: optimization of profiles and beam angles
Study results

- in 32/33 cases automatic plan was selected by physician (almost always better sparing, often also better tumor coverage)
- also objectively (DVHs, NTCP) automatic plans had higher quality.
differences between automatic and manual planning in mean OAR doses
How good is automated planning compared to ‘manual’ planning?

Prostate cancer

manuscript in preparation
**AUTOplan vs. MANplan for prostate cancer international validation**

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1 Erasmus MC Cancer Insitute, The Netherlands.
2 Elekta AB, Elekta, Stockholm, Sweden.
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4 Medical University Vienna /AKH Wien, Radiation Oncology, Vienna, Austria.
5 St James's Institute of Oncology- St James's Hospital, Leeds, United Kingdom.
6 University Medical Center Mannheim - Heidelberg University, Mannheim, Germany.
Study protocol:

For all 4 centers:

- Include VMAT plans of 30 recently treated patients
- 10/30 patients used for configuring of autoplanning algorithm
- Other 20/30 patients: AUTOVMAT vs CLINICAL
  - Dosimetric comparisons (DVH)
  - Physician side-by-side plan comparisons with scoring
### AUTOplan vs. MANplan for prostate cancer

80 (4x20) plan comparisons

<table>
<thead>
<tr>
<th></th>
<th>MAN-AUTO</th>
<th>Range</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV $V_{95%}$</td>
<td>0.0 %</td>
<td>[-4,4] %</td>
<td>1.0</td>
</tr>
<tr>
<td>rectum $D_{mean}$</td>
<td>3.9 Gy</td>
<td>[-4,12] Gy</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>rectum $V_{60\text{Gy}}$</td>
<td>4.8 %</td>
<td>[-2,15] %</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>rectum $V_{75\text{Gy}}$</td>
<td>1.3 %</td>
<td>[-3,7] %</td>
<td>0.004</td>
</tr>
<tr>
<td>bladder $D_{mean}$</td>
<td>1.28 Gy</td>
<td>[-10,10] Gy</td>
<td>0.003</td>
</tr>
<tr>
<td>bladder $V_{65\text{Gy}}$</td>
<td>-0.25 %</td>
<td>[-15,15] %</td>
<td>0.028</td>
</tr>
</tbody>
</table>
CLIN better  AUTO better

$$\Delta D_{\text{mean}} = 3.9 \text{ Gy}$$

$$P < 0.001$$
AUTOplan vs. MANplan for prostate cancer

Physician side-by-side plan scoring

- AUTO ++
- AUTO +
- EQUAL
- CLIN +
- CLIN ++
**autoVMAT:**
- conformity $\uparrow$
- dose gradient $\uparrow$
How good is automated planning compared to ‘manual’ planning?

cervical cancer

How good is automated planning compared to ‘manual’ planning?

cervical cancer

Validation of Fully Automated VMAT Plan Generation for Library-Based Plan-of-the-Day Cervical Cancer Radiotherapy

Abdul Wahab M. Sharfo*, Sebastiaan Breedveld, Peter W. J. Voet, Sabrina T. Heijkoop, Jan-Willem M. Mens, Mischa S. Hoogeman, Ben J. M. Heijmen

- 44 CT-scans of previously treated patients
- **autoVMAT vs. manVMAT expert planner, no time pressure**
AutoVMAT and manVMAT plans had highly similar PTV coverages, within the clinical constraints.

SB $V_{45Gy}$ for autoVMAT was lower than for manVMAT in 41/44 cases

- average reduction in SB $V_{45Gy}$ : 30.2% ($p<0.001$).

- Differences in bladder, rectal and sigmoid doses were <1%.

- manVMAT, hands-on planning time: 3 hours
PD = 46 Gy
20, 30, 35, 40, 43.7, 46 Gy

**autoVMAT:**
- conformality ↑
- dose gradient ↑

**manVMAT**
(expert planner, no time pressure)
How good is automated planning compared to ‘manual’ planning?

Prostate SBRT

Courtesy Linda Rossi, paper submitted
**MANplan (clinically delivered) vs. AUTOplan (restrospectively)**

(10 patients)

<table>
<thead>
<tr>
<th></th>
<th>auto</th>
<th>Clinical</th>
<th>%Diff</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PTV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V38Gy (%)</td>
<td>95.2</td>
<td>95.0</td>
<td>-0.2</td>
<td>0.853</td>
</tr>
<tr>
<td><strong>Rectum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1cc (Gy)</td>
<td>26.3</td>
<td>31.2</td>
<td>15.6</td>
<td>0.002</td>
</tr>
<tr>
<td>V60GyEq (%)</td>
<td>0.58</td>
<td>2.4</td>
<td>75.1</td>
<td>0.002</td>
</tr>
<tr>
<td>Dmean (Gy)</td>
<td>6.1</td>
<td>10.4</td>
<td>41.3</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Bladder</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1cc (Gy)</td>
<td>37.3</td>
<td>37.6</td>
<td>0.7</td>
<td>0.162</td>
</tr>
<tr>
<td>Dmean (Gy)</td>
<td>8.9</td>
<td>14.0</td>
<td>36.4</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Courtesy Linda Rossi, paper submitted
Prostate SBRT

MANplan/clinical

AUTOplan:
- conformality ↑
- dose gradient ↑

Courtesy Linda Rossi, paper submitted
Autoplanning in the IGRT era

Conclusions

- Automated planning can substantially improve quality of IMRT/VMAT dose distributions, compared to manual planning.

- Due to higher conformality and steeper dose gradients, proper CTV-PTV margins and IGRT even more important.