Erasmus MC
University Medical Center Rotterdam

Cancer Institute

Towards Automated Treatment Planning in Radiotherapy

s.breedveld@erasmusmc.nl

Sebastiaan Breedveld, Peter Voet, Steven van de Water, Abdul Wahab Sharfo, Linda Rossi and Ben Heijmen
Erasmus MC Cancer Institute, Department of Radiation Oncology, Rotterdam, The Netherlands

Introduction

Treatment plan optimization is a labour-intensive time-consuming task, with quality highly dependent on the skills and experience of the planner. The high-complexity of the problem may often result in suboptimal plans.

The aim of this PhD was to develop an algorithm for *fully automated* treatment planning, including integrated *beam angle selection* and integrated *IMRT* optimization, with *higher* plan quality than contemporary plans. This lead to the *Erasmus-iCycle* algorithm.

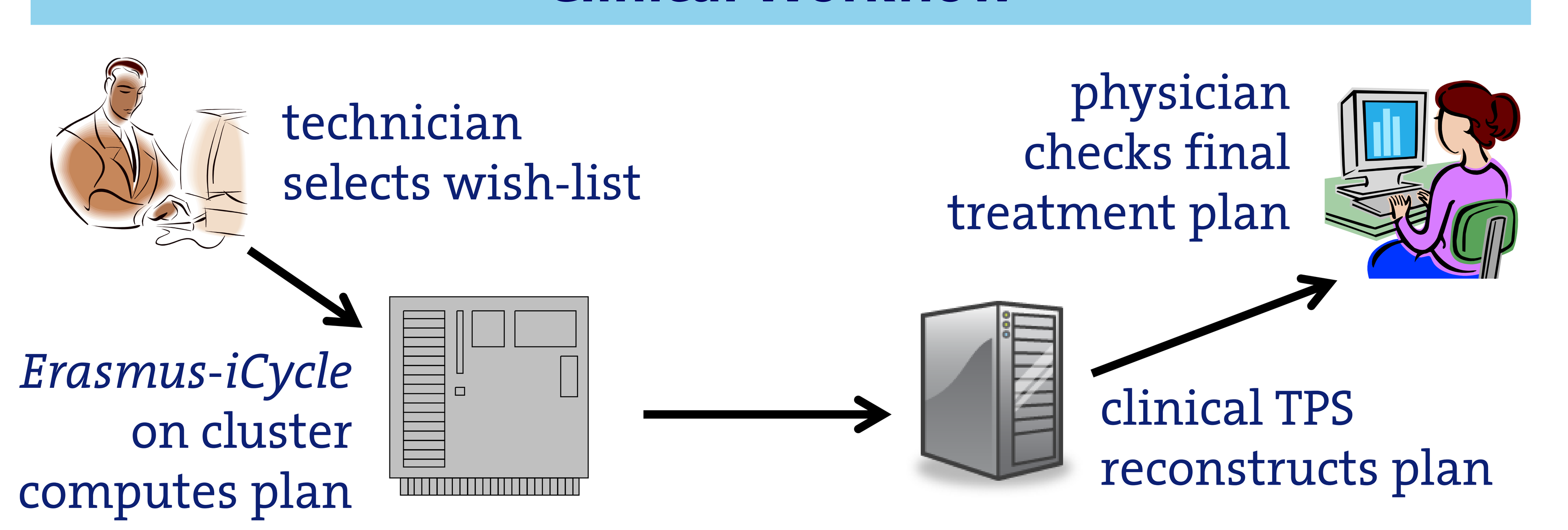
Conclusion

Treated over 800 patients since 2010, with 500 in 2013!

Erasmus-iCycle allows to:

- automatically generate treatment plans, with quality generally superior to plans made by dosimetrists and physicists.
- perform large-scale treatment-planning studies, comparing treatment strategies.
- further personalize treatment by selecting the best modality on a per-patient basis.

Clinical Workflow



Automated Multi-Criteria Optimization

The basis of automating treatment planning lies in automating the decision-making. By *a priori* defining constraints and prioritized treatment objectives, a so-called *wish-list* can be constructed. The objectives are sequentially optimized, resulting in a relevant Pareto-optimal solution without interaction.

No per-patient tuning is required, so a single *wish-list* can be used for a group of patients. The same list is used for fixed-beam setup, beam angle optimization and VMAT.

Constraints

Volume	Type	Limit
PTV	maximum	49.2 Gy
Spinal Cord	maximum	48 Gy
Salivary Glands	maximum	46 Gy

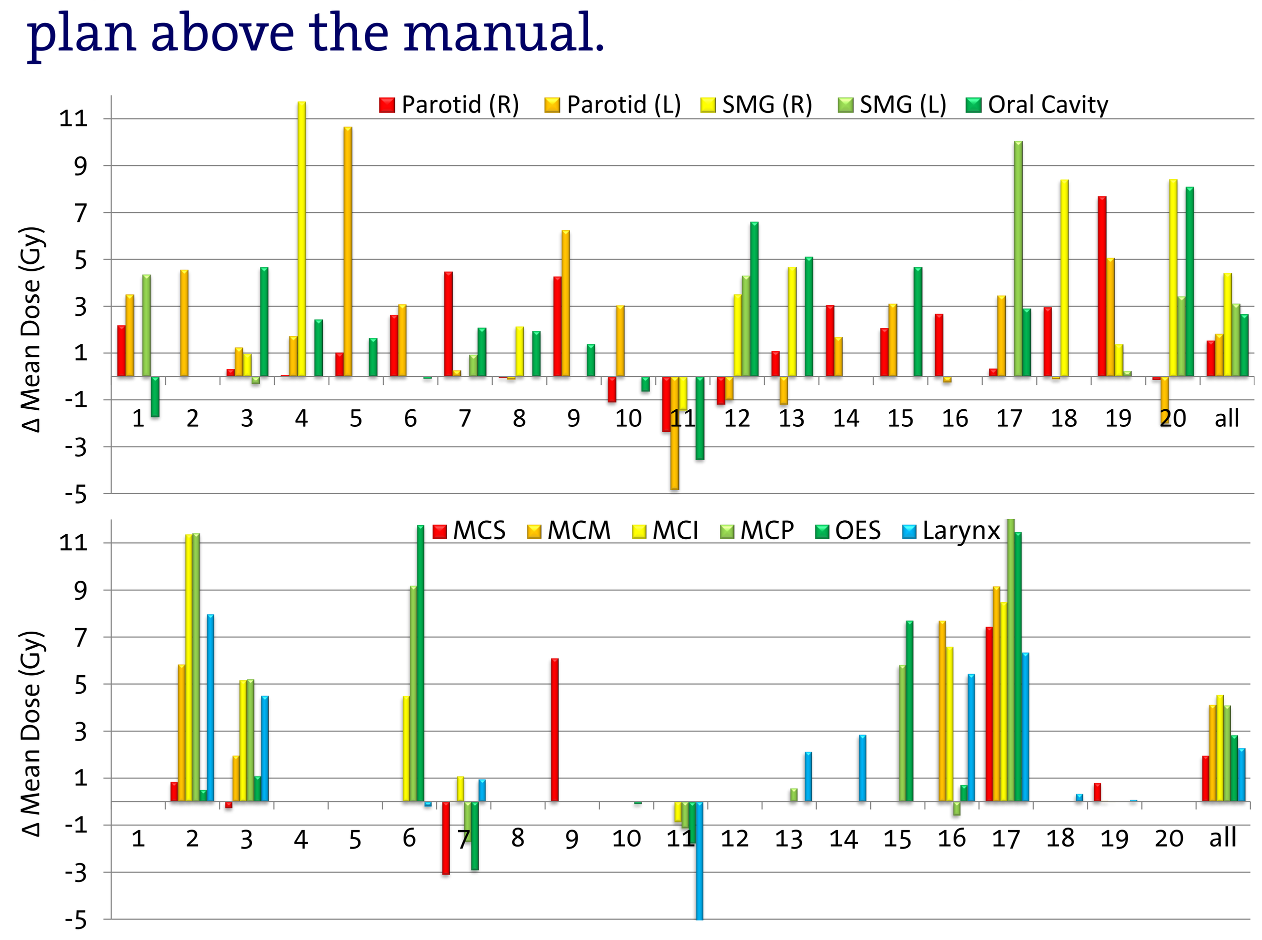
Objectives

Priority	Volume	Type (minimize)	Goal
1	PTV	LTCP	1
2	Left Parotid	mean	39 Gy
3	Right Parotid	mean	39 Gy
4	Oral Cavity	mean	39 Gy
5	Conformality Ring 1	maximum	37 Gy
6	Left Parotid	mean	20 Gy
7	Right Parotid	mean	20 Gy
8	Oral Cavity	mean	20 Gy
9	Conformality Ring 2	maximum	23 Gy
10	Spinal Cord	maximum	30 Gy
11	Swallowing Muscles	mean	35 Gy

Example wish-list for the head-and-neck site. The clinical version is much more extended and sophisticated.

Prospective Study

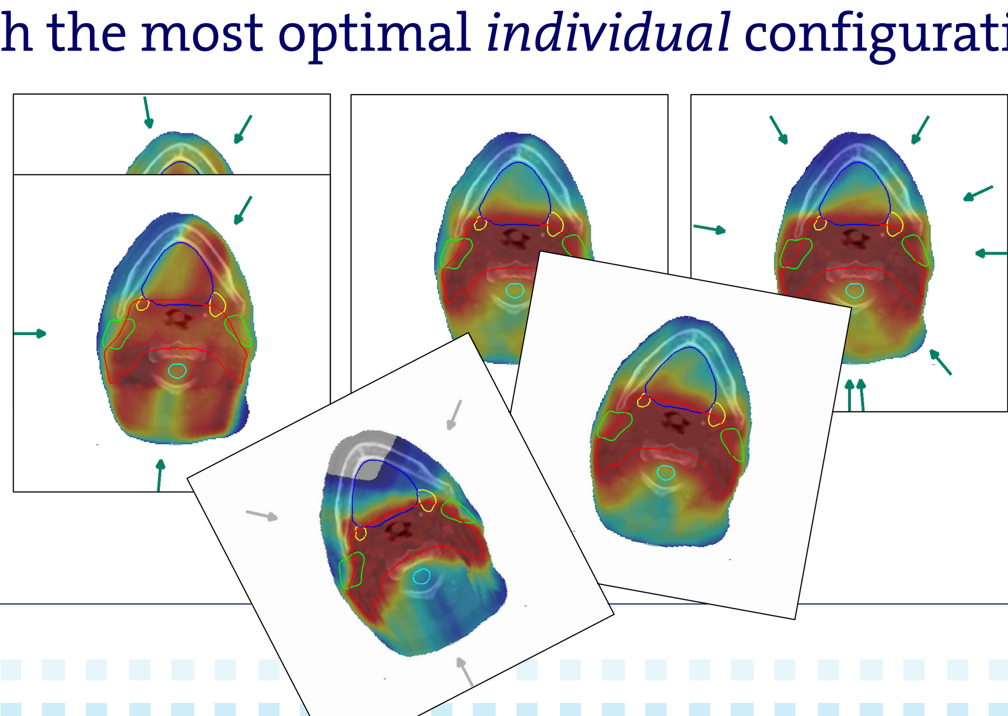
Erasmus-iCycle was clinically introduced after a prospective clinical study. In 97% of the plans, the physician preferred the automatically generated plan above the manual.



Differences in OAR mean doses, where positive values are in favour for the automated plans. For patient 11, target coverage was not attained in the manual plan, but was in the automated plan.

Personalized Treatment

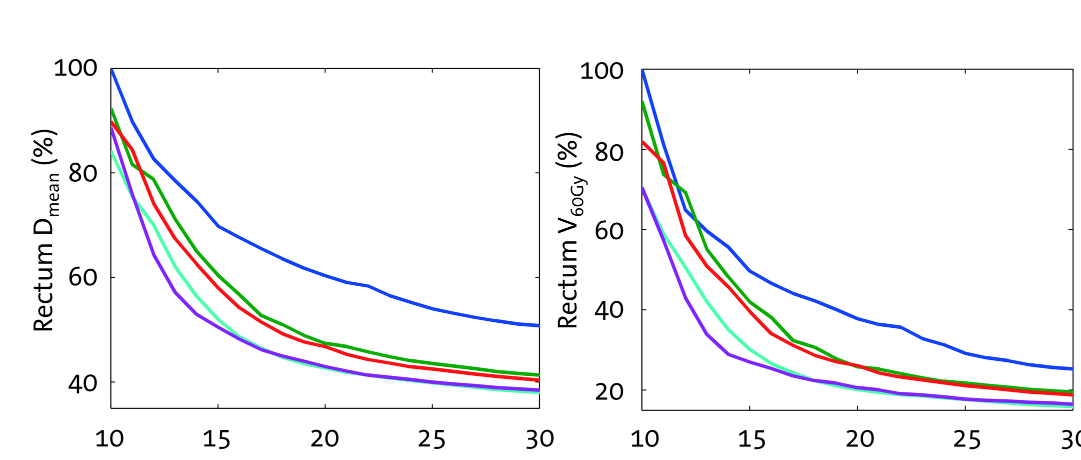
Further individualization of radiotherapy is possible by generating *for each patient* plans for multiple modalities and settings, e.g. coplanar and non-coplanar 7, 9, 11, … beams plan, VMAT, IMPT, CyberKnife, etc., rather than *a priori* specified by protocol. The patient is then treated with the most optimal *individual* configuration.



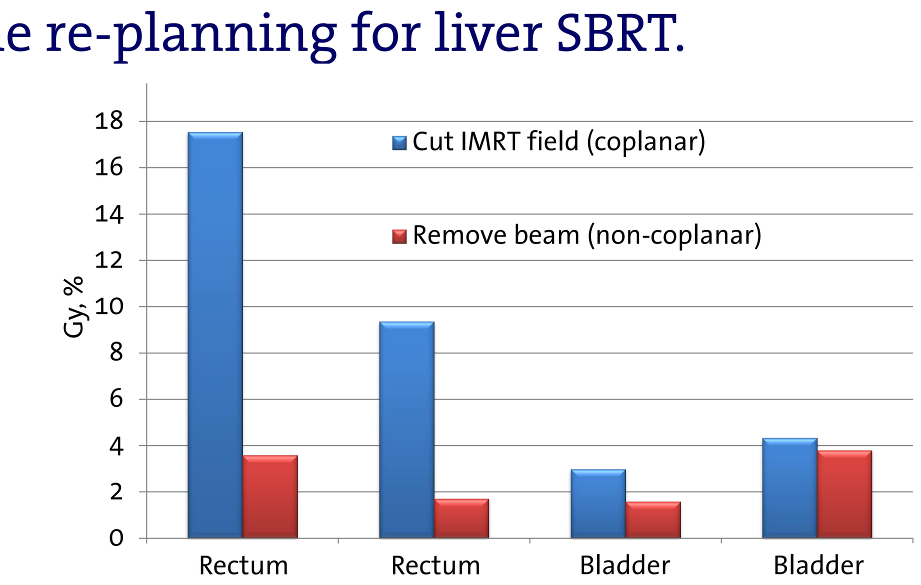
Planning Studies

The deterministic nature of *Erasmus-iCycle* allows objective treatment planning studies. As there is no planner variation, different strategies are easily tested on a large group.

Studies already performed included 1) the impact of the absence of posterior directions for the CyberKnife for prostate cancer (left), 2) prostate patients metal hip prostheses (right), 3) coplanar vs. non-coplanar, and 4) online re-planning for liver SBRT.



Convergence with number of beams, relative to the 10 beam coplanar plan (blue). Colours indicate different degrees of freedom in beam orientation. Blue = coplanar, Green is conventional CyberKnife positions, Purple fully non-coplanar. Red and Cyan extended CyberKnife node sets.



Improvement over contemporary practice for prostate cancer patients with bilateral hip prostheses, where beams passing through a prosthesis are removed completely. Cutting the IMRT field instead leads to much improved sparing (blue), while a non-coplanar removal technique (red) is only marginally better.