

Clinical evaluation of an automated adaptive proton therapy workflow using contour propagation and dose evaluation

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Introduction

Treatment quality for all patients treated with proton therapy at our facility is monitored using weekly repeat CT scans (reCTs). The target contours are manually re-delineated on all reCTs which is very time-consuming. The **purpose** of this study was to evaluate if automated CTV contour propagation would lead to the same level of adaptation as the manual workflow, and thereby allow for an automated reCT workflow.

Methods

During the first year of clinical use of our **Mevion S250i Hyperscan** proton therapy system, **79 patients** finished treatment. For all reCTs, re-evaluation of the proton plan was performed, leading to a total of **241 re-evaluations**. All plans and reCT evaluations were performed in Raystation using robust, Monte Carlo based dose calculation. To **reduce workload**, we developed and validated an automated workflow for reCT evaluation. The validation consisted of the following steps:

- Deformable image registration of the clinical target volume (CTV) structures from the planning CT to each of the following reCTs, using the hybrid method in Raystation 9A
- Extraction of the dose-volume histogram (DVH) parameters for the CTV structures, both based on the original manually re-delineated contours (CTV_{manual}) and the deformably mapped contours (CTV_{auto}); and noting if they satisfied the clinical constraint or not
- Compare the DVH parameters extracted for CTV_{manual} and CTV_{auto}, and evaluate if they lead to differences in the clinical decision, that is, if the clinical constraint was satisfied for one contour but not the other

Definitions

- **True negative:** All clinical constraints are satisfied for both CTV_{manual} and CTV_{auto}
- **True positive:** At least one clinical constraint is failing for CTV_{manual} and CTV_{auto}
- **False positive:** All clinical constraints are satisfied for CTV_{manual}, but at least one constraint fails for CTV_{auto}
- **False negative:** At least one clinical constraint fails for CTV_{manual}, but all constraints are satisfied for CTV_{auto}

False negatives are the most problematic for the automated workflow as they can cause potential adaptations to be missed.

Results

Only 9 reCTs (4%) presented with false negatives. In 92% of the reCTs, CTV_{auto} led to the same conclusion as CTV_{manual}. **Out of 241 reCTs for 79 patients, only for 1 reCT a clinical adaption was made, while the automated workflow suggested that no adaptation was needed.**

Conclusion

The CTV contour propagation was of sufficient quality for plan evaluation purposes. **The automatic workflow is being introduced clinically.**

A direct time saving of 2 hours per RTT and 1 hour per RTO, as well as the almost complete elimination of hand-over time between workflow steps is expected. This workflow will streamline the plan adaptation evaluation procedure within the same day, instead of three days as in the current practice.

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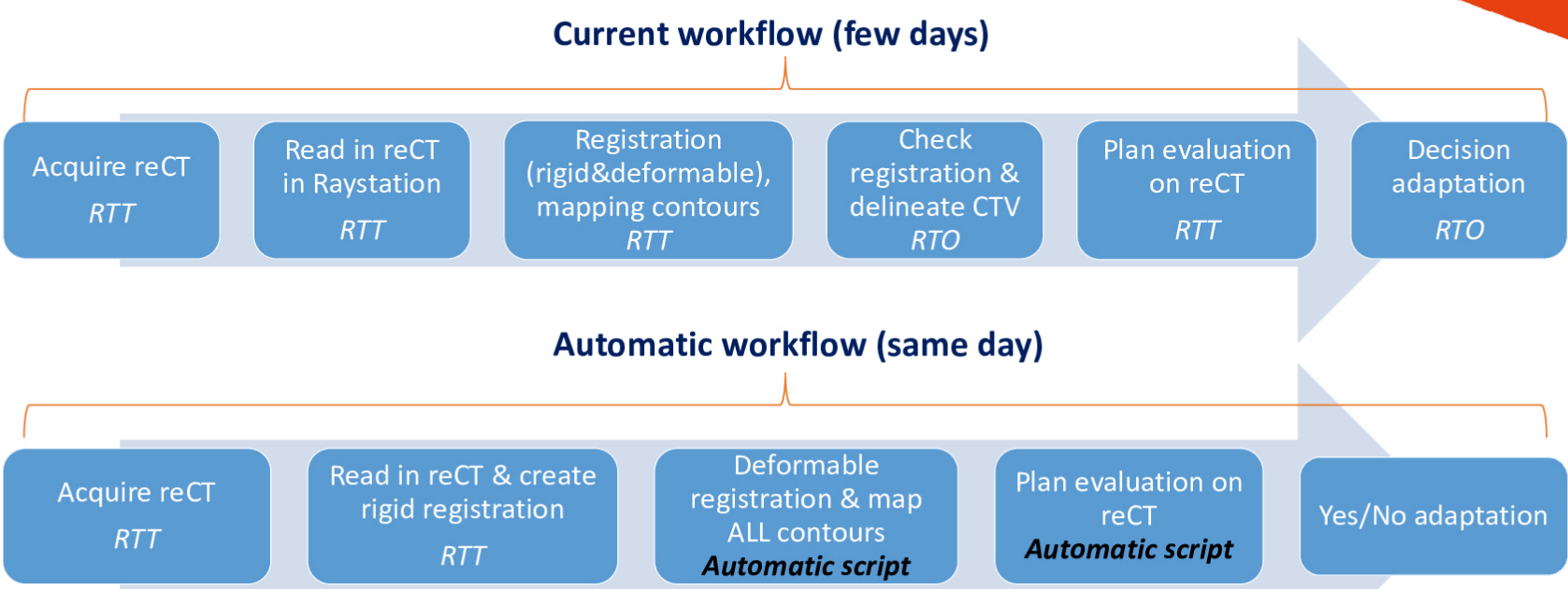


Figure 1: Schematic of the old manual workflow (top row); this manual workflow typically takes a couple of days and thereby delays the delivery of the optimal plan to the patient. The new automatic workflow (lower row) has been evaluated and clinically implemented to reduce the workload on the radiation technicians (RTTs) and radiation oncologists (RTOs). With this new workflow, the decision whether to adapt the treatment plan is reached within one day.

	Total	Brain	Head&Neck	Breast	Lung	Lymphoma
#Patients	79	12	14	35	14	4
#reCTs evaluated	241	55	61	66	50	9
#True positives (rate)	114 (47%)	31 (56%)	34 (56%)	22 (33%)	19 (38%)	8 (89%)
#True negatives (rate)	108 (45%)	24 (44%)	19 (31%)	36 (55%)	28 (56%)	1 (11%)
#False positives (rate)	10 (4%)	0 (0%)	3 (5%)	5 (8%)	2 (4%)	0 (0%)
#False negatives (rate)	9 (4%)	0 (0%)	5 (8%)	3 (5%)	1 (2%)	0 (0%)

Table 1: Statistics for the comparison between the CTV_{manual} and CTV_{auto}. In 9 of the reCTs (4%) the automatic workflow missed that the clinical goals were not met; however, in 8 out of these 9 reCTs the failing of the clinical constraint for CTV_{manual} was so minor that in practice no adaptation was needed. **Therefore only 1 adaptation would have been missed out of 241 reCTs.**