

Ph.D. Project Title: New planning concept for online adaptive and online monitored MR-linac radiotherapy

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Project Report

My Ph.D. project is about describing, evaluating and improving the planning dose distributions for online adaptive and online monitored MR-linac (MRL) radiotherapy. The aims are described as (i) to define and evaluate the geometric and temporal uncertainties in online MR-guided and online-adapted radiotherapy, and (ii) transform the found uncertainties into new planning approaches, and (iii) evaluate the dosimetric impact of the new planning approaches. Thus far we have focused on objective (iii) by conducting two dose accumulation studies which resulted in two accepted abstracts, one for MRinRT 2020 in Heidelberg and one for ASTRO 2020. The former presentation was cancelled due to the covid-19 pandemic while the latter was presented at the virtual ASTRO meeting (see the poster below). Since our first two studies were on dose accumulation using deformable image registration, we are now conducting a study on the inter-software reproducibility of such accumulations. This study will hopefully be published in 2021.

Publications


None

Poster Presentations

Heidelberg 2020: We got an abstract with the title "1 Year Experience with Liver SBRT on MR-linac: Planned vs. Delivered Dose" accepted for poster presentation. Unfortunately, this conference was postponed due to the covid-19 pandemic.

ASTRO 2020:

Dosimetric Impact of Daily Plan Adaptation in MR-Guided Liver SBRT
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PURPOSE/OBJECTIVE(S)

At our institution we treat liver metastases with stereotactic body radiotherapy (SBRT) on the magnetic resonance linear accelerator (MR-linac). This enables tracking on the liver, tumor, or tumor-adjacent structures and provides improved soft tissue visualization compared to cone beam computerized tomography. Hence the implementation of fiducials can be omitted. Another benefit of MR-guided treatment is the potential for daily plan adaptation, which we explore in this study.

MATERIAL & METHODS

10 consecutive patients were treated in a total of 41 fractions with non-adapted liver SBRT at the MR-linac. Prescribed doses were 48 Gy to 75 Gy to the gross tumor volume (GTV) in 3 to 6 fractions. GTV to planning target volume (PTV) margins were 10 mm in cranio-caudal direction and 5 mm in other directions for eight patients and isotropic 5 mm for two patients. The original plan was calculated on the MR simulation scan (original plan). There was an automatic calculation of the original plan on the daily patient anatomy (delivered plan). Dose distributions of these clinically delivered fractions were accumulated by deformable registration to the MR simulation scan. In addition we simulated an adaptive workflow retrospectively for all fractions by optimizing the original plan on the daily anatomy (optimized plan). Delivered and optimized plans were compared based on $D_{95\%}$ for the GTV and PTV, and the plan with the best coverage was chosen as the daily adapted plan (adapted plan). Adapted doses were summed by deformable registrations to the MR-simulation scan. The GTV was rigidly transferred from the MR simulation scan to the fraction MR.

RESULTS

Plans selected in the adapted workflow resulted in a median increase in $D_{95\%}$ of 0.1 percentage points (pp) (range -1.4 pp to 8.8 pp) and 2.7 pp (range -2.7 pp to 7.8 pp) of the prescription dose to GTV and PTV, respectively, compared to a non-adaptive workflow (see Table 1 below). The adaptive workflow would result in a median 3.0 cm³ decrease (range -44.8 cm³ to 24.8 cm³) in the volume of the healthy liver (liver minus GTV) receiving less than 15 Gy compared to a non-adapted workflow.

Table 1. The median of $D_{95\%}$ to GTV and PTV as percentage of prescription dose and the volume of the healthy liver receiving below 15 Gy in cm³. The numbers in brackets are the ranges. The three rightmost columns represent differences between the plans. The clinically applied constraint is that at least 700 cm³ of healthy liver receives below 15 Gy.

	Dose parameters in plans			Differences between plans		
	Original Plan	Delivered Plan	Adapted Plan	Original - Delivered	Original - Adapted	Adapted - Delivered
$D_{95\%}$ (GTV) [pp]	92.5 (79.2 to 94.6)	86.7 (89.2 to 94.8)	90.3 (72.9 to 94.9)	4.9 (-1.7 to 12.3)	2.8 (-1.8 to 6.3)	6.1 (-1.4 to 8.8)
$D_{95\%}$ (PTV) [pp]	69.2 (58.0 to 91.3)	65.2 (51.7 to 88.0)	68.5 (56.6 to 90.5)	5.9 (-1.1 to 9.5)	2.3 (-3.9 to 6.2)	2.7 (-2.7 to 7.8)
V_{15} (Liver - GTV) [cm ³]	1412.3 (998.3 to 1804.8)	1409.8 (984.4 to 1819.6)	1384.1 (996.5 to 1791.9)	3.7 (-142.1 to 73.2)	13.6 (-142.1 to 79.9)	-3.0 (-44.8 to 24.8)

THE MYSTERIOUS 10th PATIENT

One patient was omitted from the results due to problems in the dose summation (see Figure 1). The daily adapted fractions had a median $D_{95\%}$ of 56.8% (range 96.3% to 97.0%) of the fraction prescription dose but the summed fractions resulted in a median $D_{95\%}$ of 74.9% of the plan prescription dose. Watch the video to the far right to find out why this happened.

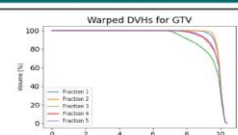


Figure 1: All five adapted fraction doses warped to the MR simulation scan for the excluded 10th patient.

SUMMARY/CONCLUSION


Online plan adaptation appears unnecessary for most patients treated with liver SBRT, with only minor improvement of target coverage and clinically non-significant dosimetric changes for the healthy liver V_{15} . For this patient group the impact of the daily geometrical match has a larger impact than online plan adaptation.

ACKNOWLEDGEMENTS

We want to acknowledge all the radiation therapy technologists, clinicians, and physicists who have been part of implementing and delivering MR-linac treatments at our institution.

VIDEO

What happened with the dose coverage for the 10th patient?



#ASTRO20

Talks

- I gave an oral presentation at the “2020 Øresund Workshop on Radiotherapy” titled “Individual planning dose distributions for online-adaptive treatments with internal MRI gating”.
- I gave a flash talk at the yearly Ph.D. Symposium at Rigshospitalet titled “Dose Accumulation Reproducibility in an MR-linac Setting”.

Project activities in 2021

- Estimate dose accumulation reproducibility for liver and lung patients treated at the MRLs at Herlev Hospital and Rigshospitalet.
- Setup 3D cine scans at the 3T MR scanner at Rigshospitalet for liver, lung and prostate patients treated at the MRL.
- Make 3D treatment cine by offline registrations of 3D MR scans and 2D treatment cines at the MRLs at Herlev Hospital and Rigshospitalet.