Progress report – November 2020

Project title: Respiratory gated photon and proton radiotherapy guided by internal tumor motion monitoring with conventional standard imager systems.

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Status of the research project

In my PhD project I have worked extensively with both tumor position monitoring and reconstruction of the actually delivered dose during radiotherapy using our in-house developed program, DoseTracker. One extension which I have focused on, is the inclusion of rotational motion of the target during dose reconstruction. The first simulations on this topic have been published recently[1] in a collaboration with my co-supervisor in Sydney, Paul Keall. Another paper is in preparation based on experiments performed with collaborators at KU Leuven (Tom Depuydt, Robin De Roover), where the rotation including calculations were done in real-time concurrently with experimental measurements of the same dose. The preliminary results are promising and I have been awarded with an oral-presentation at the largest European congress for radiotherapy, ESTRO, this year.

The results of my first paper[1] show the potential impact of prostate rotations on the dose coverage. This initial study and the experimental study conducted recently are novel in the sense that other articles investigating the impact of rotations on the prostate dose coverage have used the mean prostate rotation or similar[2,3], which does not include the dynamic interplay effects between radiation delivery and tumor motion.

For the experimental study, the patient plans included intraprostatic boosts, and the results showed significant changes to the dose delivered to the urethra when not accounting for prostate rotations.

My second project is about intrafraction dose guided patient positioning using DoseTracker. The concept of dose-guided patient positioning is not new. In dose-guided patient positioning, the dosimetrically optimal patient position is calculated based on the anatomy of the day. Similarly to IGRT methods, dose-guidance efforts have focused on interfractional anatomical changes based on pretreatment imaging, but substantial anatomical changes also occur intrafractionally due to breathing motion and tumor baseline drift[4] which causes unintended deterioration of the planned dose. In our work we propose and demonstrate a novel method for real-time intrafractional dose guidance, where the delivered dose at any given time is combined with a predicted remaining dose with and without the dosimetrically optimal couch correction.

My third project is at an earlier stage. In it, we use DoseTracker and a motion monitoring system to calculate the dose delivered to included lymph nodes stations during lung radiotherapy. The new thing in this study, is the inclusion of differential motion of the lymph nodes.

Discussion of the research plans for the remaining PhD study period

As of November 2020, I am currently writing on the dose guidance article. Following submission, I will be writing a paper on the rotation-including dose reconstruction experiments conducted in collaboration with researchers from KU Leuven. While writing, initial work will begin on analyzing data from the motion-monitoring study where data from more than 20 patients needs to be analyzed to do the aforementioned

study as well as help with another study describing the stability of deep inspiration breath-hold for intrafraction motion monitoring during lung irradiation.

Publication progress

1) The first article is a peer-reviewed conference article based on work from my masters thesis with some additions*: Dose reconstruction including dynamic six-degree of freedom motion during prostate radiotherapy*[1]

2) The second article is the intrafraction dose guidance article: *Simulation of real-time intrafraction dose guidance in liver stereotactic radiotherapy.* I expect to submit this before the end of 2020. The article is making good progress, but there are still some simulations to be made.
3) The third article is the experimental usage of DoseTracker with inclusion of rotations. All the experiments have concluded. The first results are to be presented at ESTRO2020. The article is expected to be submitted somewehere near the start of 2021.
4) The fourth article is expected to be on real-time online calculation of the dose delivered to involed lymph nodes during lung radiotherapy, where differential motion of the lymp nodes is taken into account. The contents are not set in stone, and may change based on our prelimary results.

Conference participation:

1. Oral presentation at ESTRO 38. 26-30 April 2019 in Milan, Italy
    - Abstract title: “Dose-guided motion management during liver SBRT delivery using real-time reconstructed tumor DVHs”, C. G. Muurholm, T. Ravkilde, S. Skouboe, E. Worm, R. Hansen, M. Høyer, P. J. Keall, P. R. Poulsen. Radiother Oncol 2019: 133 suppl 1; S153-S154
2. Oral presentation to be held at ESTRO2020. Online.
    - Abstract title: “Experimental validation of real-time rotation-including dose reconstruction during tumor tracking”, C. G. Muurholm, T. Ravkilde, R. De Roover, S. Skouboe, R. Hansen, W. Crijns, P. J. Keall, T. Depuydt, P. R. Poulsen
3. Poster presentation at BiGART2019 - 18th Acta Oncologica conference
    - Real-time dose-guided radiation therapy

Bibliography

1. Muurholm CG, Ravkilde T, Skouboe S, et al. Dose reconstruction including dynamic six-degree of freedom motion during prostate radiotherapy. *J Phys Conf Ser*. 2019;1305:012053. doi:10.1088/1742-6596/1305/1/012053

2. Amro H, Hamstra DA, Mcshan DL, et al. The dosimetric impact of prostate rotations during electromagnetically guided external-beam radiation therapy. *Int J Radiat Oncol Biol Phys*. 2013;85(1):230-236. doi:10.1016/j.ijrobp.2012.03.020

3. Wolf J, Nicholls J, Hunter P, Nguyen DT, Keall P, Martin J. Dosimetric impact of intrafraction rotations in stereotactic prostate radiotherapy: A subset analysis of the TROG 15.01 SPARK trial. *Radiother Oncol*. 2019;136:143-147. doi:10.1016/j.radonc.2019.04.013

4. Worm E, Høyer M, Hansen R, et al. A prospective cohort study on gated stereotactic liver radiotherapy based on continuous internal electromagnetic motion monitoring. *Int J Radiat Oncol Biol Phys*. 2018;101(2):366-375.