Göteborg, 2023

ADVANCES IN MRI-BASED RADIATION THERAPY

Bringing MRI-only and multiparametric methods towards clinical applications

AKADEMISK AVHANDLING

som för avläggande av medicine doktorsexamen vid Sahlgrenska akademin, Göteborgs universitet kommer att offentligen försvaras i Jubileumsklinikens aula, Gula stråket 2B, SU/Sahlgrenska, fredagen den 3 februari, klockan 13.00

av

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Fakultetsopponent:

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Avhandlingen baseras på följande delarbeten:

I. **Synthetic computed tomography data allows for accurate absorbed dose calculations in a magnetic resonance imaging only workflow for head and neck radiotherapy**
Palmér E, Karlsson A, Nordström F, Petruson K, Siversson C, Ljungberg M, Sohlin M.
Phys Imaging Radiat Oncol. 2021;17:36-42

II. **Head and neck cancer patient positioning using synthetic CT data in MRI-only radiation therapy**
Palmér E, Nordström F, Karlsson A, Petruson K, Ljungberg M, Sohlin M.
Journal of Applied Clinical Medical Physics. 2022;23(4):e13525

III. **Cone beam CT for QA of synthetic CT in MRI only for prostate patients**
Palmér E*, Persson E*, Ambolt P, Gustafsson C, Gunnlaugsson A, Olsson LE.
*Contributed equally to this study
Journal of Applied Clinical Medical Physics. 2018;19(6):44-52

IV. **Oxygen-enhanced and intravoxel incoherent motion MRI for detection of radiation therapy induced changes of head and neck cancer**
Palmér E, Brovall J, Jalnefjord O, Petruson K, Nordström F, Karlsson A, Ljungberg M, Sohlin M.
Manuscript

SAHLGRENSKA AKADEMIN
INSTITUTIONEN FÖR KLINISKA VETENSKAPER

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Bringing MRI-only and multiparametric methods towards clinical applications

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Abstract

MRI data have the advantage of being excellent in soft tissue contrast, therefore having an increasing imaging role in external radiation therapy (RT). Lately, attention has been directed towards MRI-only workflows, with the approach of completely excluding the original CT data as a pre-treatment imaging modality. Instead, the RT workflow is based solely on MRI data. To access the electron densities needed for calculation of the absorbed dose distribution, synthetic CT data (sCT) are generated utilizing image processing or deep learning (DL) based methods. Besides purely anatomical information for guidance of a RT workflow, many functional and microstructural properties, such as cell density, microvascular structure, perfusion, and oxygenation of the tumor, could be highly relevant for RT treatment guidance and early RT assessment. It has been proven that hypoxia has an essential role in treatment outcome for HN cancer patients receiving radiation therapy. The potential to monitor hypoxia by functional and anatomical MRI (i.e., multiparametric MRI) is sparsely evaluated, and more studies are required to be able to establish robust MRI-derived hypoxia biomarkers.

The research within this thesis aimed to validate the MRI-only workflow for head and neck (HN) cancer, by evaluating sCT data generated by a nowadays commercially available DL-based method. The geometric and dosimetric properties were compared to the original CT data (Paper I), and as they were similar it was concluded that sCT can be used for dosimetric purposes. Further, both 2D and 3D patient setup verification based on sCT data was evaluated by comparison of the verification registrations with the registrations obtained when using the original CT data (Paper II). As the registrations for sCT and CT obtained similar patient positions, it was concluded that sCT data can be used for patient setup verification. As the generation of sCT data is based on complex models, a quality assurance (QA) process was developed to assess the quality of sCT data for prostate cancer (Paper III). A comparison between calculated absorbed dose distributions based on sCT and cone beam CT (CBCT) acquired for treatment setup verification, was shown to detect intentionally introduced errors within the sCT data. In addition, the research within this thesis aimed to implement and evaluate the potential of Oxygen-Enhanced (OE) MRI, intravoxel incoherent motion (IVIM), and diffusion kurtosis imaging (DKI) to monitor hypoxia, and their potential as useful tools for early response assessment in HN cancers (Paper IV). Each of these MRI pulse sequences was optimized and successfully implemented within a clinical RT setting. By comparing MRI-derived biomarkers acquired before and during RT for HN cancer patients, changes could be monitored during the course of treatment.

The research presented in this thesis contributed to the clinical feasibility of MRI-only radiation therapy for multiple cancer types. In addition, the research showed that it is possible to implement multiparametric MRI for tumor characterization and treatment follow-up in the radiation therapy process for the complex HN region.

Keywords: MRI-only, radiation therapy, synthetic CT, IVIM, DKI, OE-MRI, cancer

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