EDITORIAL

Magnetic resonance in radiation therapy

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Magnetic resonance in radiation therapy

The integration of magnetic resonance imaging (MRI) into radiation therapy (RT) has seen a large upswing over the past several years. Significant efforts aimed at integrating MRI as a tool for image-guidance in the treatment room have yielded systems that combine MRI and teletherapy (MRgRT systems). International guidance on brachytherapy recommends the integrated use of MRI for soft tissue localization. Advances in creating wide bore MRI scanners with limited spatial distortion have supported a move towards their advancement as RT Simulators. The efforts of several groups in identifying MR scanning and analysis techniques have demonstrated several ways in which MRI can serve to provide biomarkers for prognosis, assessment, and individualization of RT, both to seek out improved local tumor control as well as to understand and nominally limit toxicity associated with RT treatments. The most unique aspect of most of these developments is that they extend beyond using existing MR scanners in conventional fashions, by introducing new hardware and system designs, pulse sequences and reconstruction methods, post-processing techniques, and clinical processes that deviate significantly from diagnostic MRI.

With the objective of forming a community to collectively discuss and encourage advanced development of MRI within the RT environment, the first ‘MR in RT’ symposium was convened in a conference room at Brigham and Women’s Hospital following the 2012 ASTRO meeting. From that conference of 30 individuals, three successive symposia were held at Washington University in St. Louis (2014), at Lunds Universitet (2015), and at the University of Michigan in Ann Arbor (2016). The latter symposium had 220 registrants from 13 nations, and presented a program that combined educational talks, symposia, debates, and most significantly 69 proffered talks and posters.

This special section presents some of the scientific work presented at the fourth MR in RT symposium. The 10 manuscripts featured cover areas such as system design, image acquisition and reconstruction, imaging as a biomarker, and clinical applications of MRI specific to RT.

In ‘A non-axial superconducting magnet design for optimized patient access and minimal SAD for use in a linac-MR hybrid: proof of concept’, Yaghoobpour Tari and colleagues investigate a MRgRT system wherein the magnet rotates with the radiation source to maintain a roughly parallel relationship to the irradiating beam. They address the challenges of providing a uniform field over a large volume with sufficient patient access through modeling a novel magnet design.

Understanding motion patterns due to breathing is an area which has seen active efforts by the radiation oncology community for well over a decade. So-called ‘4D’ imaging techniques strive to produce volumetric representations of breathing motion. In ‘Investigation of subsampling and reconstruction algorithm dependence on respiratory correlated 4D-MRI for online MR-guided RT’, Mickevicius and Paulson explore the impact of various levels of subsampling and reconstruction algorithms with the objective of obtaining volumetric motion patterns of subjects immediately at the start of MRgRT sessions.

As MR provides both improved soft tissue contrast as well as potential to probe physiological and molecular constitutions of tissue, it has seen routine use as an adjunct to computed
tomography (CT) to assist treatment planning and therapy individualization. It naturally seems advantageous to attempt to replace the information extracted from CT using MR data directly. Three manuscripts deal with development of methods to use MRI without accompanying CT scans to support treatment planning.

In ‘Synthetic CT for MRI-based liver stereotactic body radiotherapy treatment planning’, Bredfeldt and colleagues present initial efforts aimed at using a single scanning sequence to generate electron density maps in the abdomen. They provide an initial model to extract the spinal column combined with a probabilistic classification scheme for electron density assignment to voxels. In ‘Female pelvic synthetic CT generation based on joint intensity and shape analysis’, Liu and colleagues describe a technique to generate CT models of female pelvic patients using volumetric Dixon imaging and post-processing based on a combination of a shape atlas and probabilistic tissue classification. In ‘Substitute CT generation from a single ultra short time echo MRI sequence: preliminary study’, Ghose and colleagues demonstrate early results in using regression models to predict CT values from ultra-short echo time imaging of a porcine leg.

In addition to development of synthetic CT models from MRI data, investigations are ongoing related to implementation and evaluation of these solutions. In ‘Dosimetric and workflow evaluation of first commercial synthetic CT software for clinical use in pelvis’, Tyagi and colleagues describe their experiences in adopting the first commercial synthetic CT model for simulation of prostate cancer for RT. In ‘A novel method to assess dosimetric impact of system specific distortions in MRI only based radiotherapy workflow’, Gustafsson and colleagues propose a means wherein a measured distortion map is applied to assess its impact on dose calculations.

As MR-derived metrics have been shown to change in response to therapy and further have been correlated with eventual response of both tumors as well as normal tissues, several efforts have been made to identify the most reasonable temporal pattern for measuring these biomarkers to effectively react to early indications of response. In ‘Repeated diffusion MRI reveals earliest time point for stratification of radiotherapy response in brain metastases’, Faisal and colleagues demonstrate that changes in apparent diffusion coefficient from diffusion weighted MRI after roughly 21 Gy of a 10-fraction 30 Gy regimen can separate responding from non-responding brain metastases.

Several efforts are being made at understanding and optimizing MR acquisition and processing for Radiation Oncology uses. In ‘MRI micturating urethrography for improved urethral delineation in prostate radiotherapy planning: a case study’, Rai and colleagues demonstrate the ability of MRI to define the urethra through the residual urine visible on T2-weighted imaging, thus absolving the need for invasive catheterization to define the urethra as a sparing structure for stereotactic prostate treatment. In ‘Metal artifact reduction in MRI-based cervical cancer intracavitary brachytherapy’, Gach and colleagues describe the use of a metal artifact reduction sequence initially developed for orthopedic MRI to reduced distortion in proton density weighted MRI of tandem applicators, a critical step as geometric integrity of the relative radiation source and tissue positions is critical for accurate brachytherapy dosimetry.

These exemplary manuscripts are a representative sampling of the novel research that is rapidly advancing the integration of magnetic resonance in modern RT practice. There is an exciting future in the further integration of MR in RT, one that is just at the beginning of its exploration.
Guest Editors

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