MRI in Radiation Therapy

Radiation therapy is an essential component of effective cancer control with clinical evidence supporting its use in over 50% of cancer patients at some time in their course of management [1]. While early success in radiotherapy relied almost completely on the relative sensitivity of cancer and normal tissues to achieve acceptable therapeutic ratios, the past 30 years have focused on the use of technology to spatially control the shape and intensity of dose delivered within the body. Three-dimensional (3D) imaging of the body has been the critical enabler in this pursuit.

The development of computed tomography (CT) transformed medicine with dramatic reductions in exploratory surgery, the ability to provide more accurate staging in cancer, and opening the frontier of minimally-invasive interventions – a frontier that radiation therapy was perfectly positioned to explore. It is important to note that the same advances in computing that were enabling CT were at the same time advancing the computation of dose in 2D or 3D volumes for more accurate delivery of dose. The reproducibility, geometric accuracy, and common physics of CT and radiation therapy dose calculation precipitated a period of accelerated innovation in the field of radiotherapy. In many ways, CT was an ideal imaging partner for radiation therapy treatment planning – quantitative Hounsfield Units (HU), geometric accuracy, large field-of-view (FOV), reasonable cost, reliability, and a large bore to tolerate immobilization devices. It was almost too easy.

The 1970s was the decade that also heralded the advancement of nuclear magnetic resonance imaging techniques that not only generated high contrast images of the human body, but also promised to classify cancer tissues according to their proton relaxation characteristics [2, 4]. Despite the promise MR offered for use in targeting radiation therapy [3] adoption has been remarkably slow with MR-simulation installations gradually emerging in the early 2000s [5] and momentum only starting to build in earnest in the past five years [6].

This volume of MReadings highlights the 'coming of age' of MR imaging in radiation therapy where MR imaging's remarkable flexibility and scope of impact is becoming undeniable. The articles in this volume and the trends in the broader literature make it clear that MR will be more than a replacement for CT in radiation therapy. Investing in MR as a means to simply improve the quality of images and assure targeting of disease while avoiding normal tissue is attractive but not sufficiently compelling to overcome the barriers to adoption. The community is clearly looking for much more. They want MR to automate delineation of disease, non-invasively assess radiosensitivity, provide early measures of response, auto-delineate normal tissues for avoidance, and to do so with a high degree of certainty regardless of motion or context, including in the presence of an intensity modulating beam of ionizing radiation. This isn't unreasonable – radiotherapy is a highly effective curative therapy and we need to bring as much as possible to the process of treatment design and delivery to ensure we maximize the likelihood of a successful outcome for each patient.

As highlighted in the articles contained in this volume, MR is unmatched in its flexibility and seemingly unlimited capacity to extract new and impactful information about the normal and disease processes in the body. Beyond a doubt, MR imaging science and technology will continue to evolve into the foreseeable future, bringing even greater specificity and additional measures of the underlying biology. For these advances to bring real impact to patients receiving radiation therapy, the community needs to work closely with our industry partners to establish the foundational elements of MR in radiation therapy. We need to build the pipeline that makes MR have the robustness of CT while delivering so much more. This requires serious focus, investment and collaboration.

The industry needs to seriously engage in understanding the needs of radiotherapy and demonstrate commitment. The traditional approach of radiotherapy receiving 'hand-me-down' technology from other higher priority sectors of the MR industry needs to stop. The history of MR in radiotherapy is littered with token investments that seemed like 'quick wins' but resulted in half-baked 'solutions' that were often abandoned. The recent developments in MR-simulation and MR-guided radiotherapy systems demonstrate a much higher level of commitment than ever seen before and this is extremely exciting, but it remains to be seen just how committed the MR-imaging partners are to fully leveraging the underlying MR technology in these endeavors [7]. In fact, MR-guided RT systems are likely to be quite limited in the amount of MR imaging functionality released clinically for the foreseeable future.

The radiation oncologists, medical physicists, and radiotherapy technologists and their communities also need to invest. The development of new MR methods and their integration into radiotherapy practice is challenging work. Technological challenges are numerous and include assuring geometric accuracy, developing robust imaging sequences, validating image analysis methods, and calculating dose based on MR images. The development of clinical research protocols to evaluate the impact of MR technologies requires oncologists to build deep expertise in the science and technology of MR – this requires significant commitment. Hybrid MR/RT technologists will be needed –

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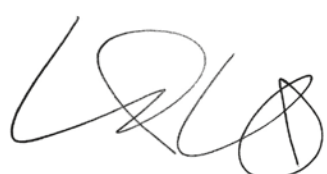
particularly in the early stages of development of these technologies – to facilitate thoughtful design of processes that are patient-centered and safe. In addition to individual commitments, the professions need to invest to build expertise and assure patient safety. To that end, the American Association of Physicists in Medicine (AAPM) has recently launched an MRI in Radiation Therapy certificate course as part of their annual meeting.

Finally, we need to look for partnerships beyond our community to deal with the deluge of MR imaging data that radiotherapy-related MR systems will produce in the future. SAR-related issues aside, MR imaging systems have the capacity to generate massive quantities of data without the dose constraints associated with X-ray based systems. Considering the value of multi-parametric sequences, multi-fraction adaptive radiotherapy, continuous monitoring for real-time tracking, it is clear that data management will be a challenge when combined with auto-segmentation, clinical decision making, re-optimization, and dose computation. Big data is often characterized by the four V's – volume, variety, velocity and veracity – efforts to engage computer scientists and consider emerging technologies such as artificial intelligence as a means to assure safety and quality of care for our patients should be considered a high priority for the advancement of MR in radiotherapy.

In summary, the promise of MR in radiation oncology paints a beautiful picture in the minds of clinicians, therapists, and physicists alike – a panacea of high contrast images streaming into semi-automated systems that deliver highly personalized cancer treatments for our patients. We need to be bold and commit to finishing this picture together with our partners in industry.



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