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Dear readers and colleagues,

Radiation therapy technology has continuously evolved since 3-dimensional (3D) conformal radiation therapy was introduced in the 1990s. The goal of conformal RT has been to provide radiation doses that hug the tumor while avoiding nearby critical organs. This 3D quantitation of tumor geometry led to the method of explicitly defining regions of suspected disease and the use of spatial margins to account for errors and variability that could not be eliminated using the current technology [1]. Image guidance further enabled the tumor and internal organs to be reproducibly positioned such that the highly conformal dose distributions matched the patient's anatomy for each treatment. This in turn allowed the reduction of margins, reducing the overall irradiated volumes and reducing toxicity [2]. This technology has allowed the quality of radiation therapy to improve treatment efficacy to the point that many modern clinical trials focus on reducing side effects as much as they focus on improving local control and ultimately long-term survival [3].

Modern radiation therapy image guidance was initiated by the commercial availability of cone-beam CT (CBCT), even though co-registered ultrasound had been available for a limited number of tumor sites, and the skull has always been an excellent bony surrogate for lesions in the brain. CBCT provides 3D anatomical information in the form of normalized tissue linear attenuation coefficients, which have contrast characterizations similar to those of conventional CT, in that low-density tissues such as lung have small attenuations, soft-tissues have moderate attenuation, and bone has the greatest attenuation. The similarity between CBCT and CT simulation images allows reference images generated using the CT simulation to be straightforwardly compared against CBCT for patient alignment.

Both the planning and delivery of conformal radiation therapy dose distributions are greatly improved when the efficacy of the imaging technology is improved. Computed tomography has been the mainstay imaging modality for radiation therapy treatment planning. Its qualities include high spatial integrity, rapid acquisition time, highly consistent and quantifiable images, reasonable contrast, and relatively low cost. On the other hand, it is relatively inflexible with respect to the type of information it gathers and provides to the clinician.

Magnetic resonance imaging shares some of the features of computed tomography, including providing a 3D image, but there are features of magnetic resonance images that are superior to those of computed tomography, specifically its improved soft tissue contrast and tremendous flexibility in design, which allows acquisition of functional image data for purposes of tumor localization, tumor biology characterization, tumor environment characterization, and radiation response information. On the other hand, magnetic resonance imaging suffers from poorer spatial integrity, and a difficulty in securing stable image quantification, especially between clinics. A great deal of effort has gone into improving the spatial integrity of magnetic resonance imaging, to the point that the spatial integrity is considered a relatively minor and manageable issue for radiation therapy.

One of the most important promises of magnetic resonance imaging is its use in radiation therapy treatment planning and assessment via MR simulation. MR simulation parallels CT simulation in that the patient is imaged in treatment position with positioning and immobilization accessories. The MR simulation procedure is typically considered as a supplement to CT simulation, but in fact the information the clinician wants to know, namely normal organ segmentation, tumor delineation, functional information, and treatment response, are better gleaned from MR simulation than CT simulation. Due to need for electron density information for treatment planning and the wide-spread adoption of X-ray or cone-beam CT based positioning, there remains a need for the information a CT simulation provides. Efforts have been made to provide that information using just an MR image dataset [4], but those efforts have not led to wide-spread adoption of what is termed MR-only simulation.

One reason for this is, as previously mentioned, CBCT is the dominant image-guided technology, so having a

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reference image with similar tissue conspicuity than the positioning image aids in patient positioning.

The introduction of MR-guided radiation therapy (MRgRT) machines, which combine magnetic resonance imaging and linear accelerators, may alter this calculus. At their most basic, these systems use magnetic resonance imaging rather than CBCT or radiographic imaging for positioning. This implies that reference images with CT-like contrast may be more difficult to use for setup. This is in fact the case; our clinic acquires a MR-simulation image using our MRgRT system so that we have a reference image that has tissue contrast that matches the contrast of the setup images. While MRgRT systems provide improved soft tissue contrast, their benefits extend much deeper. Because they can acquire images during treatment, gating with these systems is straightforward. The improved image quality also enables more accurate and sophisticated adaptive radiation therapy approaches, which have been shown to potentially improve outcomes, both for tumor control and complications [5, 6]. These features, along with clinical evidence of their effectiveness, may accelerate the adoption of MRgRT systems.

Whether MRgRT replaces a large segment of CBCT-based machines remains to be seen, but its impact on MR in RT will be significant. The radiation therapy community is paying more attention to the use of MR for treatment planning and assessment monitoring, the importance of which is being accelerated by MRgRT. This will in turn demonstrate the benefits of MR in RT to an increasingly widening array of radiation therapy departments, and since much of the benefit of MRgRT is access to an in-house MR scanner, those departments with MRgRT will themselves deepen their appreciation for the use of MR in RT. It is likely, therefore that even a relatively small adoption rate of MRgRT will further accelerate the importance and adoption of MR in RT.

The increased importance of MR imaging for radiation therapy will in turn cause radiation therapy departments to examine their roadmaps for the time when their CT simulators need replacement. Replacing one CT with another will offer limited benefits to the department, while acquiring an MR simulator will open their department to the myriad of opportunities that MR simulation offers. It will be up to the vendors and the rest of the community to make this transition painless and affordable, offering convenient and accurate simulated CT scans for their CBCT and other X-ray related alignment tools. These clinics will in turn thrive, offering their patients the benefits of improved treatment accuracy and functional-response based adaptation. When a radiation oncology department owns the MR scanner, it will be willing and able to conduct the necessary quality control to provide stable image values that AI algorithms will need to optimally function. Ideally the CT to MR trend will snowball to the point that MR simulation will displace CT simulation, providing the clinician with the benefits of improved image quality and process automation.

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