MRI and cancer radiotherapy

As I write this editorial I see dawn's silhouette through the trees, the first rays from the sun, and the promise of the new day. We are also seeing the dawn of MRI in radiotherapy as its own specialty, confirmed by the fast-growing annual international meeting held in Sydney, Australia in 2017 and Utrecht in the Netherlands this year[1]. These meetings demonstrate the clinical, scientific and industrial interest in maximizing the role and value of MRI in cancer radiotherapy.

Of the estimated 17 million new cancers diagnosed in 2018[2], evidence suggests 48% of these patients [1] – more than 8 million – should be treated with radiotherapy. The good news is that due to the reduction in smoking and advances in early detection and treatment that cancer mortality is dropping nearly 2% per year[3].

In this editorial I will briefly describe a few areas where MRI is and could change clinical practice and outcomes in radiotherapy.

MRI as the primary tool to delineate the cancer target in radiotherapy

MRI is generally acknowledged as the best imaging modality to differentiate soft tissue, but is challenging to provide the underlying image data and geometric fidelity needed for the accurate radiation transport required for modern radiotherapy planning. Through the development of elegant new methods, e.g. [2], and careful understanding and addressing each source of error in the treatment pathway [3], MRI-only planning[4] is becoming mainstream in some centers. MRI-only planning has the benefits of avoiding the imaging dose, cost and additional work associated with CT scanning, and can also reduce some uncertainties, such as the MRI to CT registration challenge. In this issue you will find articles describing the role of MRI-only planning for prostate cancer [4], head and neck cancer [5], proton therapy [6], stereotactic radiosurgery [7] and the central role of MRI in image-guided brachytherapy [8]. Collectively, these articles represent a myriad of approaches that bring MRI as the central modality for one of the most critical and uncertain steps in the cancer radiotherapy process, target delineation. Hopefully the role of MRI can reduce uncertainty, improve consistency and allow us to better understand the spatiotemporal nature of tumor and normal tissue response to radiotherapy.

MRI for dose escalation

One of the most attractive features of MRI is the broad availability of ways to measure tumor physiology, such as the spectroscopic MRI [9] study discussed here. The use of functional MRI opens up new opportunities for selective dose escalation, to provide increased amounts of radiation to the parts of the tumors that are most aggressive, radioresistant and/or have high metastatic potential. I personally feel this is one of the most exciting applications of MRI in radiotherapy with the potential to have a significant impact on cancer outcomes.

MRI for motion assessment

The description of the use of MRI to measure laryngeal motion [10] is one example of the role of MRI for motion assessment, quantification and margin assessment for radiotherapy. Studies in the larynx and other sites reinforce the complexity of motion where not only the primary target but surrounding critical tissues can be moving, rotating and deforming due to normal physiological function such as breathing, swallowing and digesting. The ability to measure complex motion for individual patients creates opportunities for personalized medicine, to give the appropriate patient-specific margin maximizing the probability of tumor coverage and minimizing normal tissue toxicity on an individual level.

MRI for response assessment

Two articles in this issue describe the role of MRI in tumor response [11], as well as normal tissue response [12]. Serial MRI, with its exquisite soft tissue imaging capabilities, will enable us to get a much better understanding of radiation effects on cancer and normal anatomy, providing us with addition information to inform future radiobiological response models and treatment plans.

The growth of 4D MRI

Two articles in this issue [13, 14] describe the investigation of 4D MRI methods which is an active area of research and development. It is interesting to draw a parallel between 4D MRI and the development of 4D CT imaging in the early 2000s. 4D CT imaging started with a few centers developing in-house solutions. Once vendors enabled the technology the technology uptake was approximately

[1] www.mrinrt2018.com
[2] https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/annual-cancer-facts-and- figures/2018/cancer-facts-and-figures-2018.pdf
[3] https://www.cancer.org/latest-news/facts-and-figures-2018-rate-of-deaths-from-cancer-continues-decline.html
[4] The product is not commercially available. Radiotherapy where MR data is the only imaging information is ongoing research. The concepts and information presented in this article are based on research and are not commercially available. Its future availability cannot be ensured. Not for clinical use.
[5] https://www.henryford.com/news/2017/07/viewray-firstpatient

7% per year resulting in over 40% of centers offering this technology by 2009 [15]. 4D CT is now a mainstream tool for lung cancer radiotherapy. It will be interesting to watch the growth and transition of 4D MRI from an investigative tool to a mainstream clinical instrument.

MRI as the primary tool to track cancer during treatment

2017 was an amazing year for integrated MRI-Linear accelerators (MRI-Linacs). The first MRI-Linac patient treatments were performed in Utrecht [16] and ViewRay successfully transitioned its MRIdian system from a cobalt radioisotope to a linac source, with the first patients treated at Henry Ford Hospital[5]. Adaptive radiotherapy, a long standing challenge for traditional linacs, has become mainstream on ViewRay's integrated radiotherapy systems [17]. The early clinical findings for pancreas cancer [18] have raised tremendous interest in the community and, if validated, will transform patterns of care for many cancer patients.

MRI to unleash the potential of proton therapy?

Based on the physics and multiple planning studies, would expect particle therapy to show markedly reduced clinical toxicity. However, the data to date which includes a retrospective SEER database medical claims review for prostate cancer [19], systematic review of early stage lung cancer [20] and prospective randomized clinical lung cancer trial [21] have yet to unequivocally clinically realize this expectation. This mismatch between expected and observed outcomes leads to a compelling hypothesis: advanced image guidance – the ultimate being real-time MRI – is required to unleash the clinical potential of particle therapy. A recent Future of Medical Physics paper reviews and describes the potential and barriers for MRI-guided particle therapy [22].

Research is global as reflected by the varied contributions to this issue of MReadings. It is heartening to see researchers from 'down-under' active in the topics discussed and providing three articles for this issue.

Enjoy!

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