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MRI GUIDED RADIATION THERAPY

Mohammed Afifi[1], Ghadeer Naser Alharbi[2], Abdulaziz Mohammed Haddad[2], Bayan Ibrahim Hakami[2], Salihah Mohammed Khormi[2], Shrooq Mohammad Alqahtani

[1] Hospital General Alwajh
[2] Jazan University
[3] King Khalid Unveiling

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Abstract

Introduction: *Radiation therapy (RT) remains to be one of the mainstays in the treatment of cancer. Recently many efforts have been made to integrate MRI into clinical RT planning and monitoring. This integration is known as MRI-guided radiotherapy. MRI-guided RT includes superior soft-tissue contrast, organ motion visualization. This recent advance is able to monitor tumor and tissue physiologic changes by the use of MRI compared with other modalities such as computed tomography. One of the common modalities used among these is Offline MRI which is already in use at many institutions. But further, MRI-guided linear accelerator systems allow the use of MRI during treatment as well, which has the advantage of improved adaptation to anatomic changes between RT fractions. Such a development in MRI guidance provides the basis for a paradigm change in treatment planning, monitoring, and adaptation. The major changes include real-time volumetric anatomic imaging, reproducible quantitative imaging across different MRI systems, and biologic validation of quantitative imaging, as well as addressing the disadvantage of image distortion because of magnetic field inhomogeneities.*

Aim of the Study: *This review describes promising inventions in offline and online MRI-guided RT and further opportunities they offer for advancing research and clinical care, including various hurdles to be overcome and the need for a multidisciplinary approach for the same.*

Methodology: *The review is all-inclusive research of PUBMED since the year 2011 to 2021*

Conclusion: *MRI-guided radiation therapy (RT) can be the next big step in RT, overcoming various disadvantages of CT guidance and offering better opportunities for the treatment of cancer. There is an improved interaction and intrafraction adaptation, dose accumulation mapping, and the use of MRI biomarkers. This kind of advancement needs a multidisciplinary approach with strong collaboration among radiologists, radiation oncologists, physicists, other imaging researchers, engineers, and data scientists. This collaboration and multidisciplinary clinical research in advanced clinical radiation oncology may provide an efficient result in treatment outcomes. The MRI-guided Linear Accelerator Consortium can be proven as an ideal platform to validate the potential benefits of MRI-guided RT.*

Keywords: *Magnetic resonance imaging; MR-guided radiation therapy; radiation oncology; radiation oncology imaging.*

Corresponding author:
Mohammed Afifi,
Hospital General Alwajh

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INTRODUCTION:

Radiation therapy (RT) remains to be one of the major treatment options for cancer for many decades. More than 40% of patients with cancer undergo radiotherapy at least once for curative or palliative treatment worldwide. For many years, there has been a major advancement in treatment delivery for such cases. These advancements are the result of immense research and great extent by innovations in imaging guidance. The first step was initiated in the 1990s by the use of three-dimensional CT imaging guidance and computers for adaptive treatment (i.e., the ability to change the treatment plan and the treatment delivery on the basis of imaging technology and diagnostics). Further, it led to three-dimensional conformal RT, stereotactic body RT planning, and intensity-modulated RT; this, in turn, has dramatically improved conformity of the dose distribution to the target volume and reduced radiation volume, and improved outcomes. [1]

This major advancement in radiation oncology is focused on improving tumor control and improving patient compliance by reducing side effects and impairment of quality of life for patients' post-radiotherapy. [2] Technological advancement in radiation therapy is proven to be advantageous for its increased conformity allowing dose escalation and hypofractionation. Image-guided radiation therapy (IGRT) includes imaging of tumors and critical structures on the treatment machine just prior to irradiation so as to improve the accuracy of treatment. This improves the convenience of treatment for patients by shortening treatment time and maintaining or lowering treatment toxicity. But the adoption of such new technology in radiation oncology is not always clinically significant and beneficial, as proven by a recent randomized trial among prostate cancer patients, showed improved biochemical and clinical progression-free interval and decreased acute and late rectal toxicity while others did not show any improvement in patient-reported outcomes. [3,4]

MRI guided radiotherapy can be broadly divided as:[2]

1. Online MRI-guided Radiotherapy
2. Offline MRI-guided Radiotherapy

Offline MRI-Guided Radiotherapy

Offline MRI simulation makes use of an immobilization device that will be used at treatment delivery, used to position the patient as closely as possible to (to simulate) the treatment position. There is a loss of signal-to-noise ratio with the immobilization device despite being MRI compatible because of the increased distance between the patient and the receiver coil. Many efforts are in process to develop flexible receiver coils to be inserted between the immobilization device and patient to increase the signal-to-noise ratio. Another major development in the integration of MRI in radiotherapy has been based on the application of pseudo-CT density and synthetic CT; this allows MRI-only treatment planning by using the Hounsfield unit assigned to each voxel. The application of MRI simulation with synthetic CT in prostate treatment planning can be seen in the figure below. [5-7]

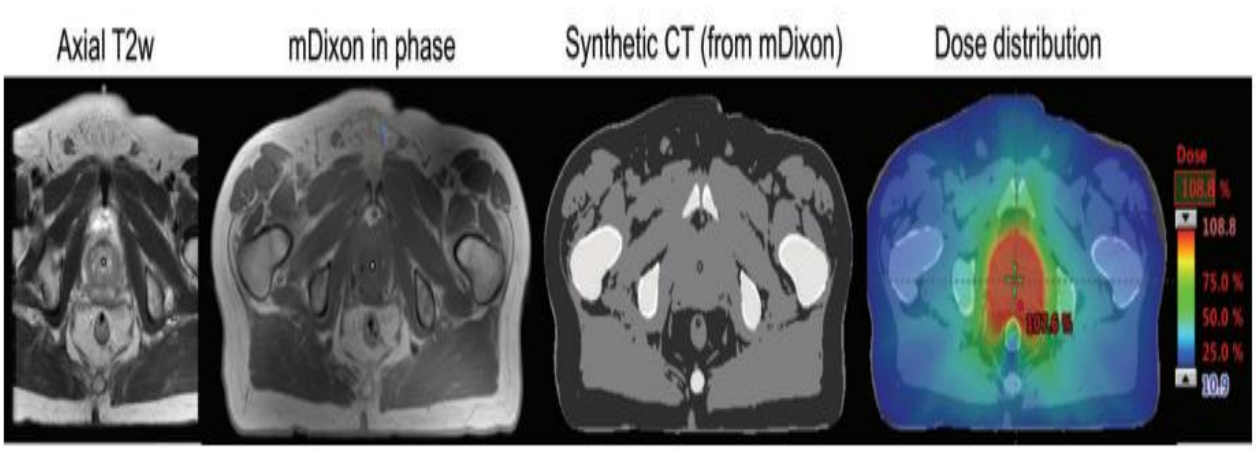


Figure showing compared with CT, MRI enables better visualization of the intraprostatic anatomy and better definition of the glandular prostate tissue within the periprostatic fat. [2]

Online MRI-Guided Radiotherapy

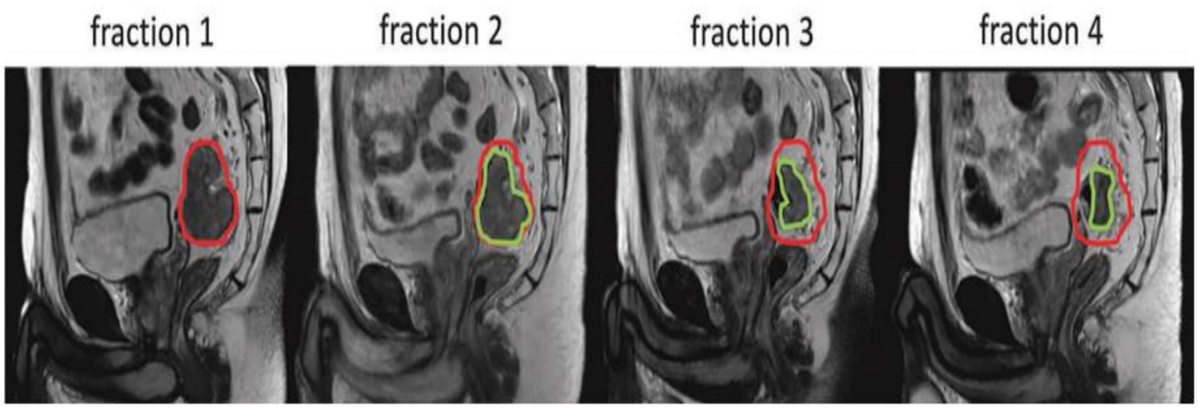
Online MRI-guided radiotherapy occurs during the treatment session by using hybrid MRI-guided linear accelerator systems; this emerging technology offers opportunities for real-time intrafraction and interaction adaptation to organ motion and calculation of dose accumulation. [2,8,9]

MRI-linac systems are one such system present globally that combines an MRI with a linear accelerator with the promise of overcoming the main drawbacks such as in photon scattering; there is relatively poor soft-tissue contrast and poor image quality. In addition, it irradiates large volumes of tissues at a low dose (range of 10 mSv per image), which in turn reduces continuous acquisition and prevents intrafraction motion assessment of cone-beam computed tomography in relation to anatomic imaging as well as adding the potential of physiologic imaging. Several types of commercial or research MRI-linacs are available as follow: [2,8-10]

Online MRI- guided Radiation therapy Pioneer Systems	
0.35-T MRI whole-body scanner, 70-cm bore	6-MV linear accelerator
1.5-T MRI scanner; Philips Achieva, 70-cm bore	7-MV linear accelerator (Elekta)
0.6-T MRI scanner, 60-cm gap	6-MV linear accelerator (research system)
1-T MRI scanner; 50-cm gap	6-MV linear accelerator (design study

[10]

Because of the system geometry, all the recently clinically approved systems are limited to coplanar irradiation. The MRI allows the improved soft-tissue contrast for better lesion delineation for treatment without the use of a contrast agent. This has been commonly shown for prostate, nasopharynx, rectal, brain tumors, and hepatic lesions. The MRI-linac proved to be advantageous in improved visualization of organs at risk, with possibilities for avoiding geographic and simultaneously reducing uncertainty margins. [8-11]



The figure shows adaptation to interfraction anatomic changes in a patient with rectal cancer, where the ability to adapt treatment to the exact location and size of the tumor improved the outcome and resulted in tumor remission. [2]

Clinical Challenges

1. Effectiveness and cost-effectiveness

For a clinically relevant outcome, the advent of new technologies requires evidence of benefit with economic advantage in order to become recognized and implemented in routine practices and superior to that of standard therapy. With MRI-guided radiotherapy, there is the potential for decreased tumor control through adaptation, e.g., via decreased dose to microscopic disease, although according to a dosimetric study, it did not predict reduced dose coverage with ART in lung cancer. [12,13]

Cost-effectiveness and its critical analysis for new technologies are essential,140 given their increasing cost over the last many decades. The initial costs of the MRI guided radiotherapy systems may be offset because of the ability to treat patients with shorter duration of time and treatment courses which in turn may improve access for people with restricted access to radiation therapy services and further decrease the costs for treatment through improved disease control and toxicities reduction.[14]

2. Clinician education and team-based treatment delivery

When compared to cone-beam computed tomography-guided therapy, MRI-guided radiotherapy systems are being operated by teams of radiographers, physicians, oncologists, and physicists because of the diverse and complex tasks required to deliver during treatment. This requires a multidisciplinary team approach and significant coordination among them, which is logistically difficult. Thus, the idea of extended/ enhanced or overlapping roles between these disciplines is needed to be studied and requirements made in keeping with local definitions of scope of practice. The introduction of MRI-guided radiotherapy requires clinician education for image interpretation, especially with an enlarging number of fMRI sequences. [15,16]

CONCLUSION:

MRI-guided radiotherapy is evolving into a promising method to individualize radiation therapy according to different patients. It incorporates online and offline imaging, adaptive radiation therapy, real-time motion management, and functional imaging to possibly improve patient outcomes through enhanced precision, conformality, and selection for treatment. Technological advances have led to MRI-guided radiotherapy systems being introduced in clinical practice over the last five years, and the future role of the innovative technology in improving daily for a promising outcome of the diseases.

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