QUALITY ASSURANCE OF A HEAD & NECK MR-SIM PROTOCOL FOR RADIATION THERAPY

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At the National Center for Cancer Care & Research (NCCCR) in Doha, Qatar, the Optima™ MR450w 1.5T wide bore system was introduced in 2010, specifically for MR-based localization and treatment simulation (MR-SIM). The scanner, featuring GE's new Geometry Embracing Method (GEM) RT Open Head & Neck Suite—first used worldwide by the NCCCR—was commissioned for radiation therapy (RT) applications. Particular consideration was taken to geometric fidelity and coil configurations to complement the MR-compatible accessory equipment needed for MR-SIM.

The program has been successfully implemented and the range of patients benefiting has increased significantly. This article focuses on studies carried out at NCCCR to validate the head and neck MR-SIM protocols.

The conventional RT workflow for a head and neck cancer patient commences with a primary CT scan of the treatment area, acquired with a wide bore scanner to accommodate the patient accessories and immobilization devices needed for treatment delivery. The patient is positioned for CT as per treatment, using a common laser system on a flat couch top with a thermoplastic mask and customized head cushion. The target volume for treatment is then delineated on the CT images, as well as healthy tissue and organs to be avoided during treatment planning. MR is increasingly being used for volume definition as it has been shown to be highly accurate with improved interobserver contouring variation.[1] Hence, not only is MR useful in oncology for staging and assessment of tumor response, but its role has developed into a powerful tool for image guided radiation therapy (IGRT).

Figure 1. Large field-of-view phantom.

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As the scanner was commissioned for MR guidance, it was important to ensure geometric fidelity for a large field-of-view (FOV) encompassing the full patient volume. In RT treatment planning, accurate dose calculation is dependent on geometrically precise representation of the entire volume—including the body outline. Hence, for commissioning and routine quality control of MR-SIM, system-related geometric distortion needs to be monitored. For this purpose, a large FOV phantom was developed in-house, allowing assessment over a FOV of 420 mm. The methodology is important as the translation of MR into radiation oncology is still relatively new. This study gives the clinician increased confidence in the accuracy and precision of MR in this emerging workspace.

The phantom was first scanned in CT to provide a "ground truth" reference for analysis and subsequently, in MR-SIM using the integrated body coil. Typical MR-SIM sequences were acquired for RT planning after application of GRADWARP (3D distortion correction algorithm). As expected, distortion increased with distance from the center. Distortion for a radial distance of 15 cm from "ground truth" was determined: for 2D FSE sequences 89% of points < 1 mm; 3D Cube 93% < 1 mm; and for 3D SPGR 88% < 1 mm. From this data a clinical protocol was developed to define a useable FOV determined from the radial distribution of points in the phantom, with a mean geometric distortion of < 2.0 mm for a scan length of 15 cm. The impact of orientation of image acquisition was quantified and it was found not to modify the useable FOV.

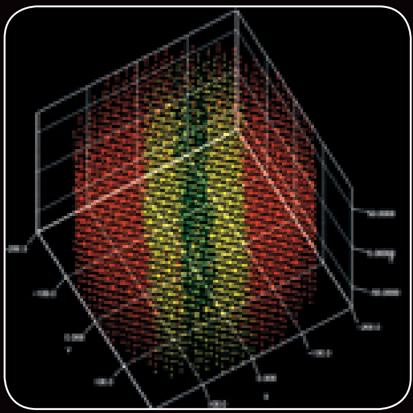


Figure 2. Example of distribution of geometric distortions for T1 FSE, demonstrating how distortion increases with increasing distance from the center.

During initial system commissioning, optimization testing was carried out to assess the imaging performance of the MR-SIM protocol for head and neck. The aim was to evaluate the impact of the addition of the RT immobilization, positioning, and coil arrangement on image quality compared with a standard diagnostic approach. Imaging protocols were optimized on repeat volunteer scanning. Each volunteer was imaged using standard diagnostic sequences and positioning, with a standard head, neck, and spine coil that served as a benchmark for image quality. They were then re-imaged as per MR-SIM immobilized with a thermoplastic mask and vacuum head cushion. The GEM Suite of coils covered the head, neck, and thoracic region. It consists of a pair of 6-channel Flex coils (head), combined with a 16-channel anterior Flex coil (thorax), and an 8-channel posterior coil embedded in the table top to help improve posterior signal coverage—allowing imaging coverage of 50 cm (L) x 39 cm (W).

The acquired images were assessed quantitatively and qualitatively in a blinded analysis. For RT treatment planning of head and neck, the volume of interest is from the base of the brain to the clavicles to visualize and discriminate the primary tumor, nodal volumes, and organs at risk. Quantitative testing illustrated good SNR for all evaluated structures. However, for the RT system, superficial anatomic structures had very high signal, whereas for deeper structures

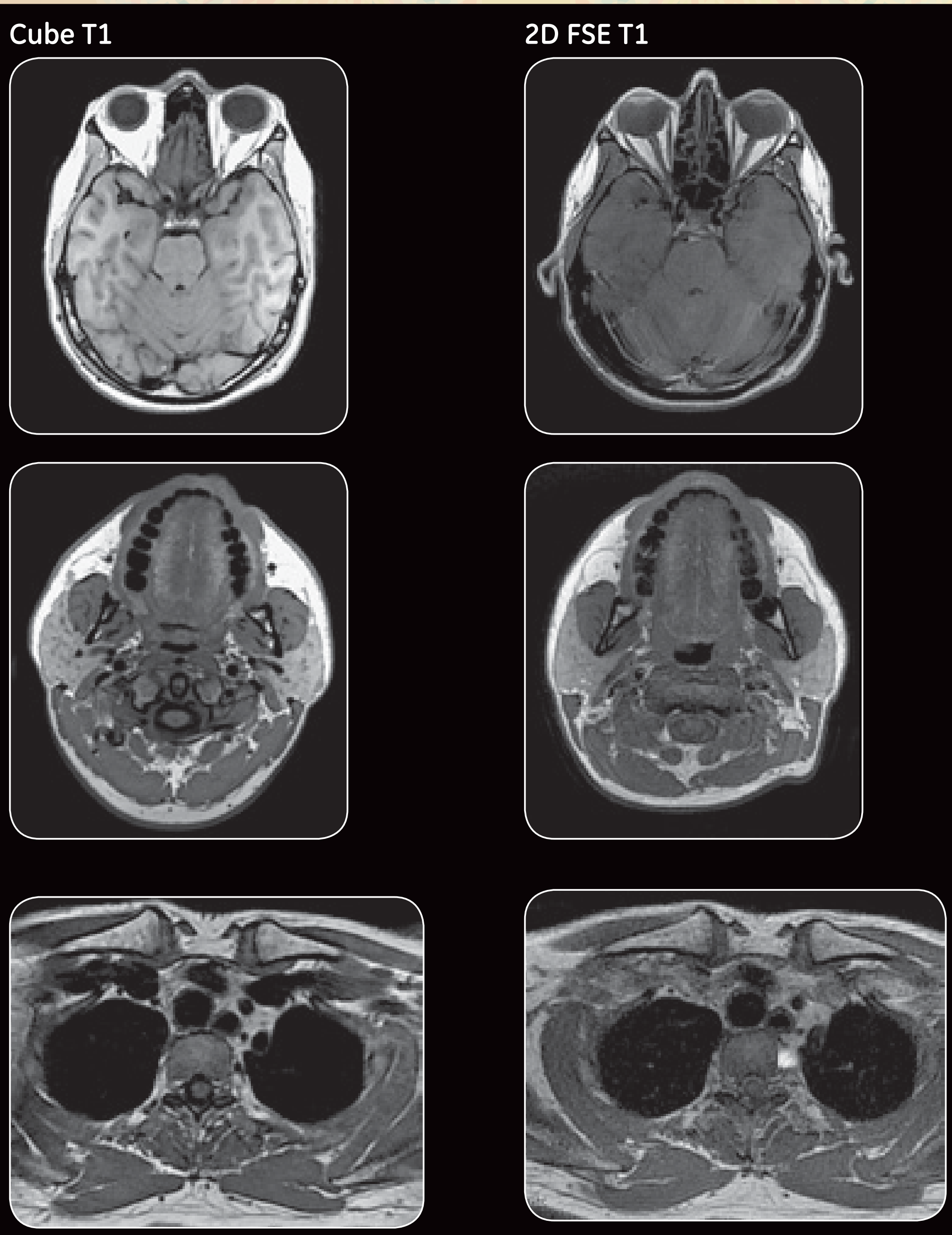
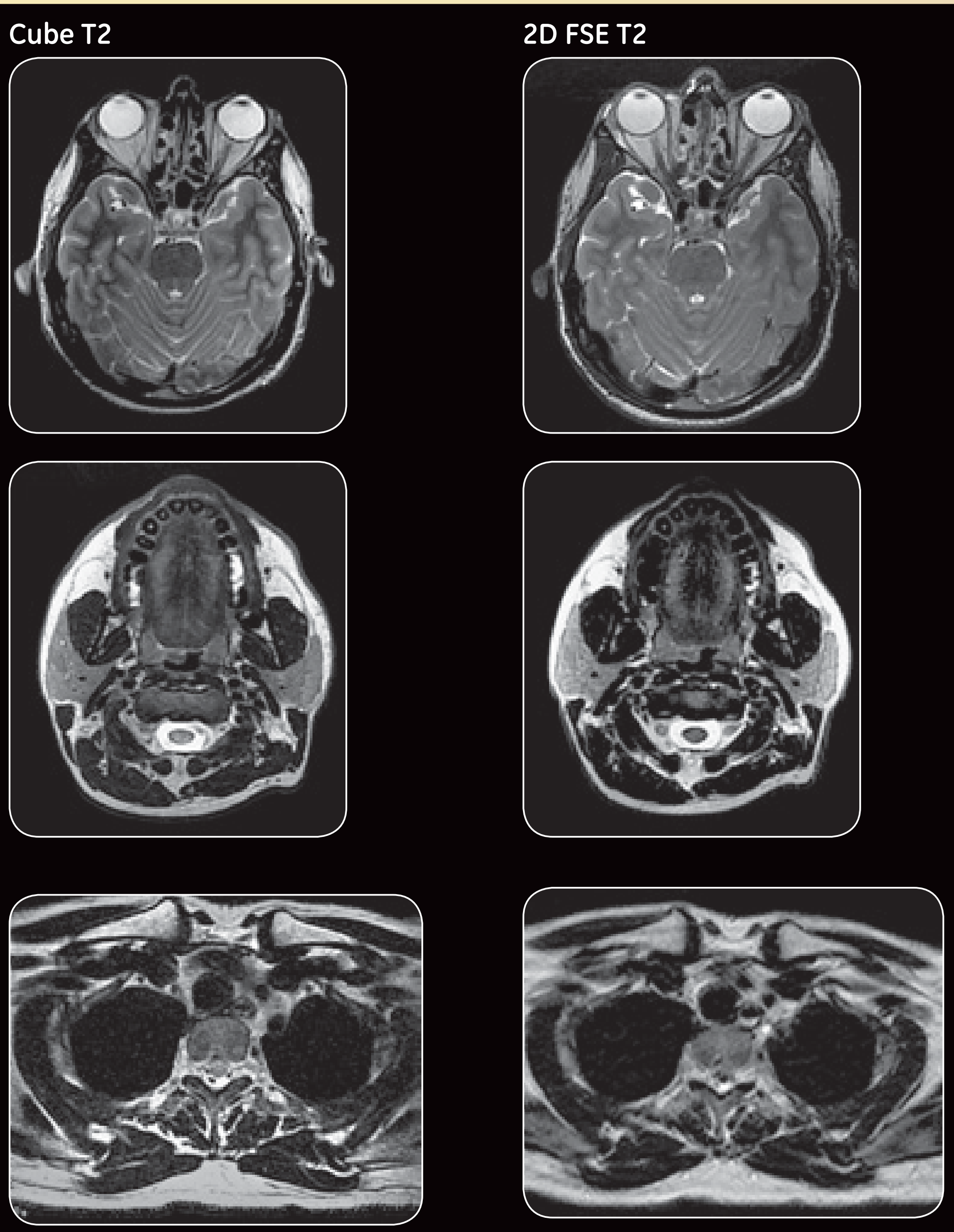


Figure 3. For RT planning, Cube was compared to standard 2D FSE images for head and neck MR-SIM. SNR was significantly higher in the 3D Cube than 2D FSE images.

the converse was true. Overall, the coil configuration (GEM Suite) provided good SNR, CNR, and signal uniformity when benchmarked against the standard DI head coil—despite the presence of the immobilization system and associated accessories. The observers rated both protocols adequate for clinical use. The adaptable architecture of the GEM Suite system complements the MR-SIM application and has since been implemented into our routine clinical practice.

The use of Cube (3D volumetric FSE sequences) for RT planning was explored for head and neck MR-SIM and benchmarked against standard 2D FSE images (Figure 4). Isotropic source data allowing arbitrary plane reformatting is particularly advantageous for RT planning as images need to be acquired axially for registration to planning CT images



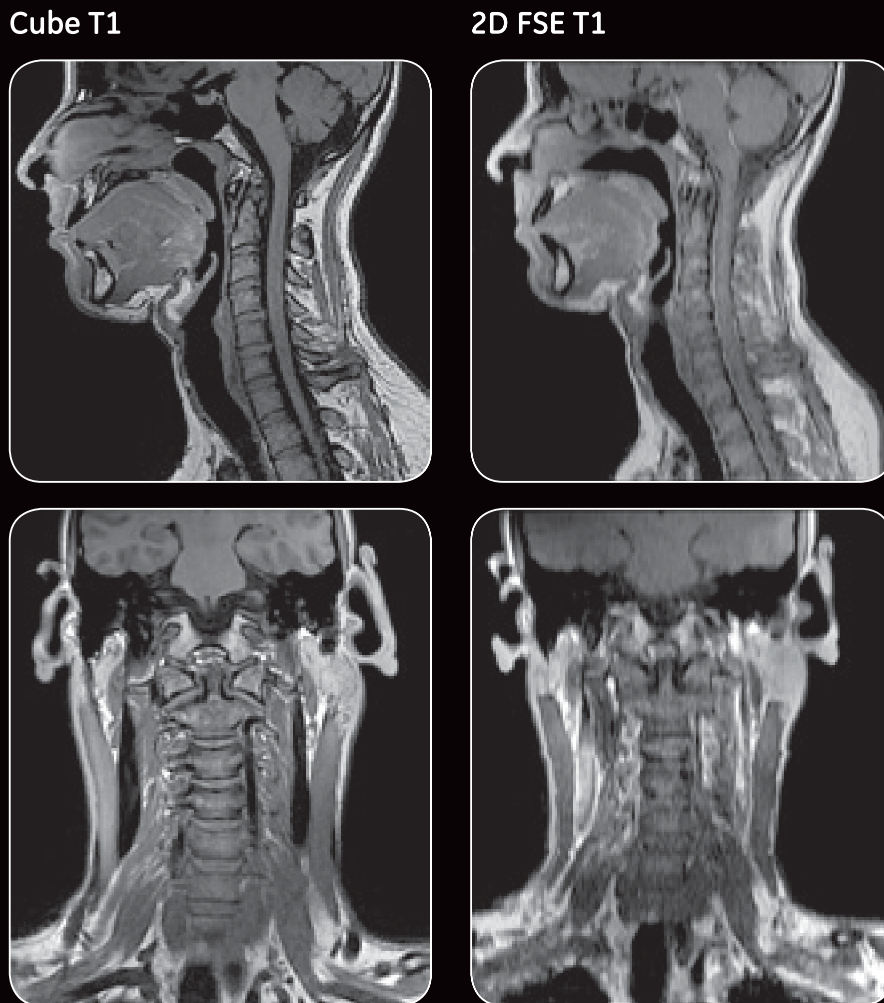


Figure 4. Radiotherapy images need to be acquired Axially. Cube allows Axially acquired images to be reformatted in any plane without resolution loss compared to the Sagittal reformats of Axially acquired 2D FSE. Note the lack of any "blurriness" in the reformatted Cube images.

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for dose calculation. Cube provides excellent resolution reformats in any plane due to the isotropic acquisition. Image quality of Cube for RT planning was assessed in a blinded qualitative assessment at our facility and it was favored in 80% of cases by radiation oncologists for delineation purposes.

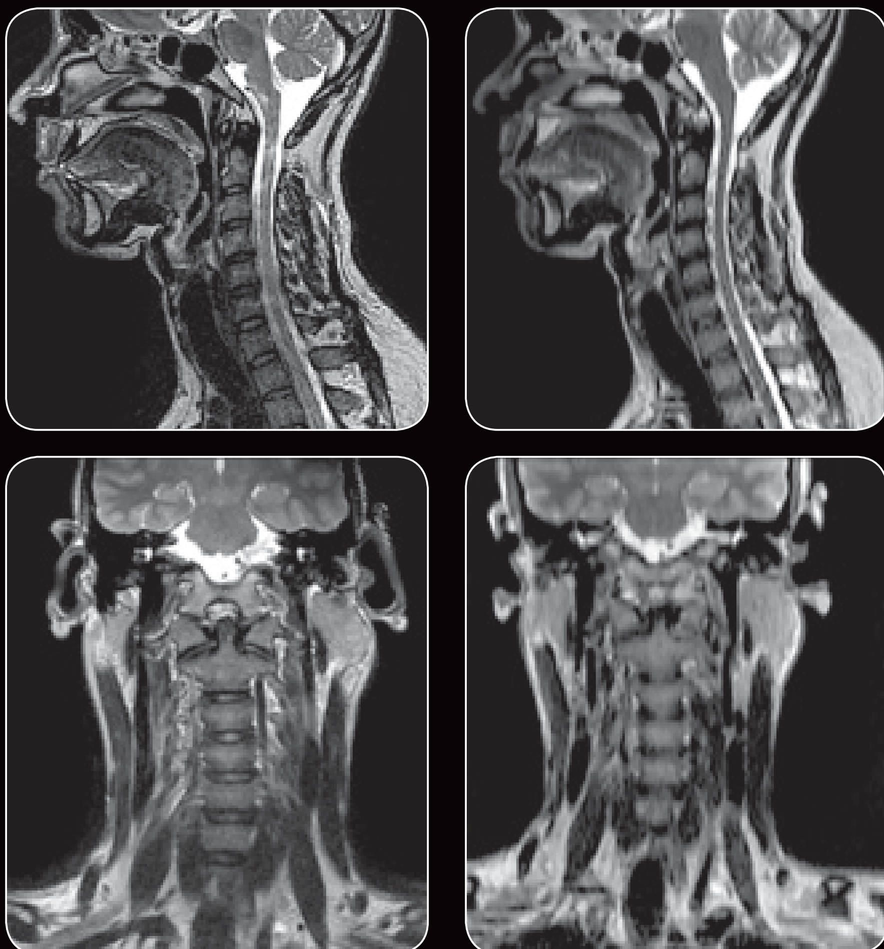
Cube sequences have since been implemented into our routine head and neck protocol and have been extended to further treatment sites, including the pelvis.

Routine implementation of MR-SIM is now a clinical reality given wide bore imaging capabilities, geometric distortion correction algorithms, MR-compatible accessory equipment, adaptable coil configurations, and today's advanced pulse sequences. S

References

1. Gardner M. Halimi P, Valinta D, et al. Use of single MRI and 18F-FDG PET-CT scans in both diagnosis and radiotherapy treatment planning in patients with head and neck cancer: Advantage on target volume and critical organ delineation. Head & Neck, April 2009;31(4): 461-467.

Cube T2 | **2D FSE T2**



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The Department of Radiation Oncology at the National Center for Cancer Care & Research (NCCCR) *in Doha, Qatar is a JCI and IAEA accredited center of cancer excellence serving the state of Qatar. State-of-the-art radiation oncology services include VMAT treatment delivery, 6D-guided frameless stereotactic radiosurgery, MR-guided brachytherapy, and PET-CT with gating capabilities.*