3D mapping of geometric distortion using static and moving table acquisitions for radiotherapy treatment planning applications

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Target audience:

Radiation oncology medical physicists, therapists and oncologists

Purpose:

MRI is increasingly used for radiotherapy treatment planning (RTP). Geometric accuracy is essential when imaging patients for the purposes of RTP and geometric distortions in MR images must therefore be considered. Commercial distortion phantoms to date have been limited for this purpose. We have developed a portable full FOV phantom to fully quantify system distortions on our RTP dedicated MRI scanner. This phantom was used to assess variations in geometric distortions observed during image acquisition utilising a continuously moving table, compared to a conventional static table. Continuous moving table acquisition allows for a longer scan length than achievable with static acquisition, a potential advantage for application for RTP. The geometric limitations of each acquisition technique with regard to their application for radiotherapy were investigated.

Methods:

A new full field of view (FOV) phantom for measuring MRI geometric distortion for the purposes of RTP was designed in-house. It was constructed from layers of Dotmar Uniboard with vitamin E capsules placed in a cylindrical pattern throughout. Phantom dimensions were 500 mm x 350 mm x 513 mm (x,y,z respectively), encompassing a total of 5830 grid points. The phantom was scanned on a dedicated RTP Siemens 3 T Skyra. A spoiled gradient echo (GRE) sequence with a 3D correction algorithm applied was utilised to image the phantom with a static table and a continuously moving table (TimCT). A standard spin echo sequence (2D correction algorithm applied) with a static table was also acquired. The phantom was scanned with CT to provide the gold standard measurement. MR images were registered to the CT of the phantom to obtain distortion maps. Images were rigidly registered using a robust block matching algorithm and non-rigid registered using a b-spline deformation algorithm. Regions where distortions were less than 2 mm were considered clinically acceptable.

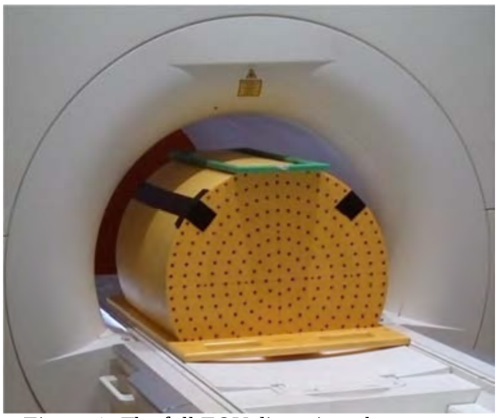

Figure 1: The full FOV distortion phantom

Results:

Figure 1 shows a photograph of the phantom being positioned on the scanner. Maximum distortions for the spoiled GRE static, 1mm/s and 2mm/s table speed acquisitions were 6.1 mm, 4.4 mm and 5.8 mm respectively. The maximum distortion for the static SE was 7.9 mm. Its geometric performance was worse than the static GRE since it only allowed for the application of a 2D correction algorithm rather than 3D. Figure 2 shows distortion vector maps for the spoiled GRE static and TimCT acquisitions. TimCT allowed imaging of the whole phantom, with only 71% of the phantom imaged with static table acquisition. TimCT acquired with a table speed of 1.1 mm/s resulted in the best geometric accuracy. Increasing the table speed to 2 mm/s decreased the acquisition time, but resulted in increased blurring within the image. The number of grid points experiencing greater than 2 mm consequently increased by 26 % and were then observed closer to the centre of the image compared to the static acquisition.

Discussion:

The phantom has been used to successfully evaluate a full volumetric mapping of system distortions on our RTP scanner. TimCT offers a potential alternative for large field acquisition for RTP, providing a more consistent distortion pattern compared to static table acquisition and a reduction in the magnitude of distortions over the longer FOV. TimCT was however limited on the scanner investigated to 2 possible imaging sequences. This may not be adequate for imaging various anatomical sites for tumour and organ delineation for RTP. It is also limited by blurring affects due to an increasing table speed and acquisition time.

Conclusions:

The developed phantom is essential for assessing geometric distortions across a large FOV as required for RTP. Both static and moving table MR image acquisitions are viable scanning options for imaging for RTP. Selection of the acquisition technique would depend on the anatomical region under investigation.

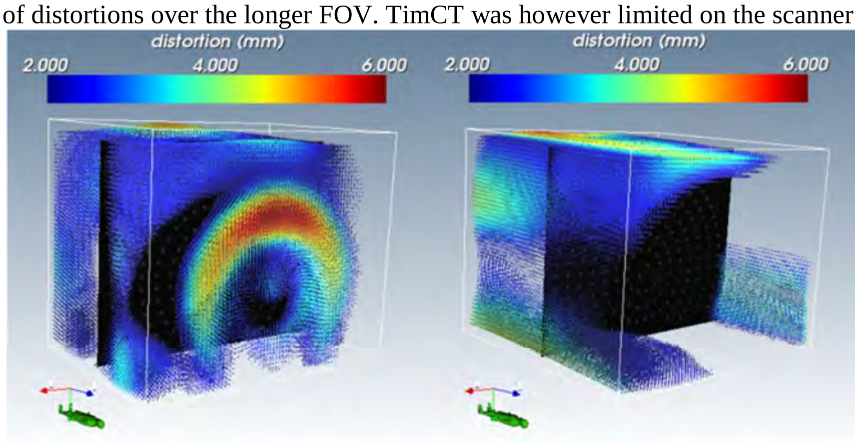

Figure 2: Vector fields indicating distortion greater than 2 mm for static acquisition (left) and TimCT with table speed of1.1 mm/s (right)