A three-dimensional Magnetic Resonance Imaging geometric distortion correction algorithm for radiotherapy

S. Hanvey[1], and J. Foster[2]
[1]Radiotherapy Physics, Beatson West of Scotland Cancer Centre, Glasgow, Lanarkshire, United Kingdom, [2]MRI Physics, Beatson West of Scotland Cancer Centre, Glasgow, United Kingdom

Introduction: One of the most important aspects of radiotherapy is accurately defining the gross tumour volume and its relationship to organs at risk. Current external beam radiotherapy planning techniques normally use computed tomography (CT) datasets to obtain axial slices of the body. Due to the superior soft-tissue contrast from Magnetic Resonance Imaging (MRI), many tumours are better visualised and there is improved localization of adjacent soft tissue compared to CT. MR is therefore recognized as being a useful addition to the radiotherapy process and many publications have reported modified tumour volumes using MR compared to CT. It has also been established that brain cancer patients can be imaged in the radiotherapy position with suitable image quality [Hanvey *et al*]. One of the main obstacles to using MR image sets in radiation treatment planning is geometric distortion. This study used a variety of test objects to measure the accuracy of a currently used 2D distortion correction algorithm and a new 3D distortion correction algorithm, known as 3D GradWarp.

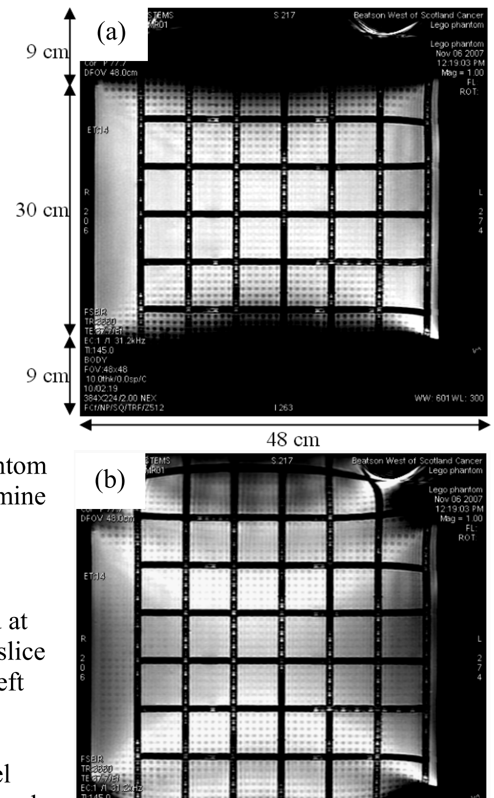

Figure 1 Coronal image of LEGO® phantom with (a) 2D correction and (b) 3D correction.

Methods: Through plane distortion was measured using a Eurospin test object T03 with three slices using the integrated body coil. The couch was moved positioning the T03 phantom 75 mm to 225 mm superior and inferior to the isocentre in increments of 25 mm. To determine the distortion correction accuracy of 3D GradWarp with multiple slices the MagNET slice position phantom was used. This is a Perspex phantom filled with a paramagnetic solution with two 90° angled rods and four parallel glass rods. Thirty-nine interleaved 5 mm thick slices with zero spacing between slices were taken with the centre of test object positioned at 50 mm increments up to 200 mm superior and inferior to the scanner isocentre. Using the slice position test object in-plane distortion was measured for the top left parallel rod. The top left parallel rod location was measured at the scanner isocentre plane for both the 2D and 3D distortion corrected scans. At isocentre, distortion is at a minimum and so this coordinate location became a reference for all other measurements. The location of the top left parallel rod was measured for slices with the phantom centred at isocentre and at 200 mm inferior and superior to isocentre. An in-plane error was calculated as the difference between the isocentre reference location and all other slice positions. Finally, to test the 3D GradWarp correction algorithm in the coronal plane, across the entire 48×48 cm field of view (FOV) a bespoke phantom was constructed using LEGO® bricks, as shown in figure 1. The extent of the warping at the central furthest edge superior and inferior to the isocentre was determined by imaging a catheter filled with saline within a recess of the table. This same catheter was first positioned at the isocentre plane where there is very little image distortion. Taking the difference between the slice positions at which the saline filled catheter was visible gave a measure of the coronal through-plane distortion.

Results: No statistically significant difference was found between the 2D and 3D distortion correction algorithms using three axial slices through a TO3 slice position error phantom along the isocentre plane. Increasing the number of slices to 39 it was found at a slice position of 270mm inferior the slice position error was 0.2 mm and 0.3 mm for the 2D and 3D distortion correction algorithms respectively. At 270 mm superior to isocentre the 2D and 3D slice position error was measured as 1 mm and 31.4 mm respectively. In-plane distortion measurements show that the 3D distortion correction algorithm reduced the error from 12.9 mm to the right and 2.6 mm anteriorly using the 2D correction to 0.7 mm to the right and 1.6 mm posteriorly at 285mm superior to isocentre. This significant improvement was not seen in the inferior direction where the error was almost the same. Using the LEGO® Phantom it was found that within the central superior and inferior edges of the FOV 3D GradWarp corrected up to 4.0 ± 0.5 cm.

Conclusions: The large difference between the correction algorithms in the superior direction is due to dissimilarity in the way in which 3D GradWarp corrects. Since the algorithm has not been optimized for the scanner the correction is prone to error. 3D distortion correction is of great importance as MRI becomes more heavily employed in radiotherapy. Clearly, a safe range for its use in radiotherapy must be rigorously tested at each centre. Making gradient field map measurements at each scanner and correcting the algorithm accordingly will improve the accuracy of 3D GradWarp thereby increasing the confidence of MRI in radiotherapy planning for the future.

References: [1] Hanvey S, Glegg M, Foster J 2009 Magnetic resonance imaging for radiotherapy planning of brain cancer patients using immobilization and surface coils *Physics in Medicine and Biology* **54** 5381- 5394.