Evaluation of Geometric Distortions of Radiosurgery MRI Protocols for three MR Scanners

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INTRODUCTION

The Leksell Gamma Knife® Icon™ allows for mask fixation and cone beam CT simulation which introduces flexibility for MRI scanning. Having pre-plan MR imaging without frame is the most modern Gamma Knife workflow. We treat radiosurgery patients with very tight margins and precise treatment setup. The spatial accuracy of images for target and normal organ delineations is critical and it is one of the important factors for a successful treatment.

Commonly, gradient field nonlinearities and nonuniformities in the main magnetic field cause geometric distortions. The radiosurgery protocols were optimized to improve geometric errors applying an option of distortion correction. For higher SNR, protocols were built at 3 Tesla field strengths. The radiosurgery protocol was set up and optimized in a 1.5T MR scanner as well for patients with implants that cannot be imaged at 3 Tesla.

PURPOSE

The MRI scanners used for radiosurgery planning were limited to three systems, and the protocols were optimized without a stereotactic frame. The purpose of this study is to analyze the geometric distortions of two 3T MR and one 1.5T MR imagers.

METHOD

The CIRS MR distortion & image fusion head phantom (Model 603-GS) was scanned with T1 MPRAGE 1 mm and T2 SPACE 1 mm series in two Siemens MAGNETOM Skyra 3T MR scanners and one GE 1.5T SIGNA™ Artist.

An online distortion check application from CIRS was used to analyze the actual and detected coordinates of the grid intersection points over the entire MRI image of the CIRS MRI distortion phantom.

DICOM images of the results for distortion between the detected grid intersections were imported to MIM® and presented as distortion map overlay to the MRI scans to visualize the distortion corresponding to their locations in the images. Iso-distortion lines were generated to show the magnitude of the geometric distortions.

RESULTS

The maximal errors of T1 MPRAGE/T2 SPACE for two 3T MRIs and 1.5T MRI are 1.051 / 0.979 mm, 1.004 / 1.056 mm and 1.096 / 0.967 mm, respectively. The average errors of T1 MPRAGE/T2 SPACE from two 3T MRIs and 1.5T MRI are 0.4228 / 0.3721 mm, 0.4136 / 0.4348 mm and 0.3182 / 0.3280 mm, respectively. The results for the two 3T MRI scanners were similar. The 1.5T MRI scanner had smaller average distortion error, as we expected.

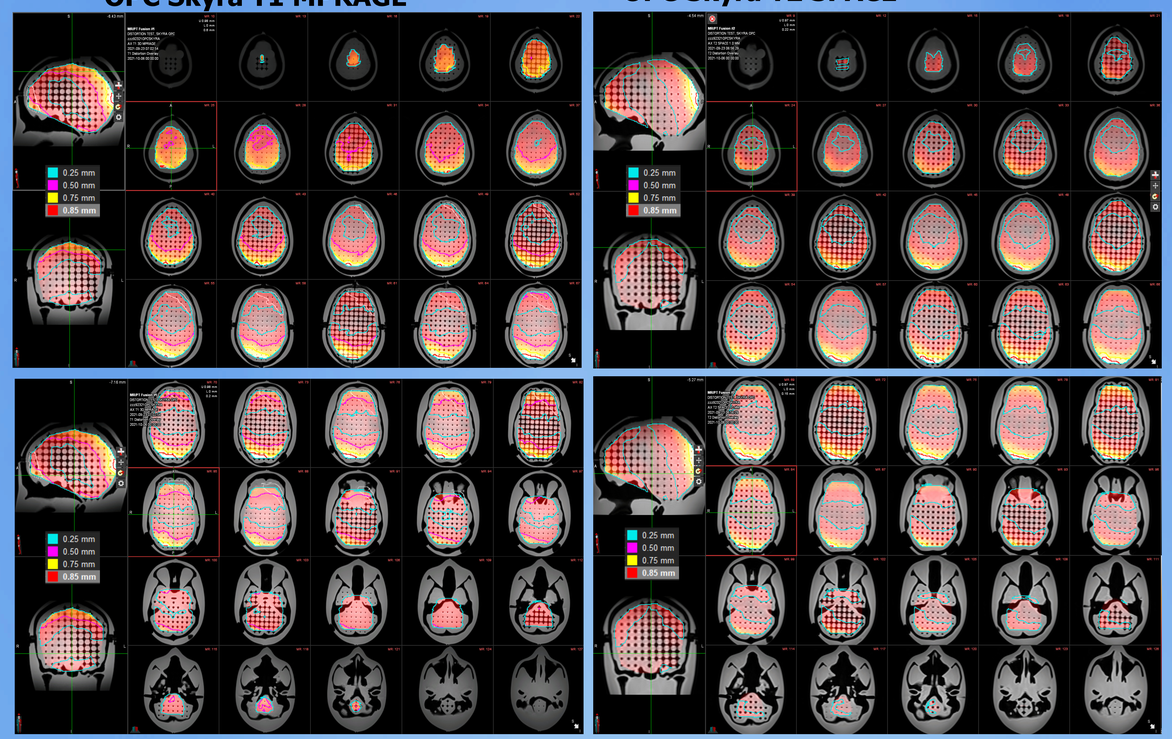
MRI	Sequence	Max Error (mm)	Max Error Location	Average Error (mm)
OPC SIEMENS Skyra 3T	T1 MPRAGE	1.051	80 mm Spherical Band	0.4228
	T2 SPACE	0.979	80 mm Spherical Band	0.3721
WT SIEMENS Skyra 3T	T1 MPRAGE	1.004	70 mm Spherical Band	0.4136
	T2 SPACE	1.056	70 mm Spherical Band	0.4348
GE ARTIST 1.5T	T1 MPRAGE	1.096	80 mm Spherical Band	0.3182
	T2 SPACE	0.967	75 mm Spherical Band	0.3280

The figures on the right display the metal hot images mapping on the head phantom images for one 3T MRI scanner and the 1.5T MRI scanner. Brighter color means larger distortion. The iso-distortion lines are also shown. The 1.5T images show that the worst distortion is at the inferior frontal location. Large distortions in the 3T images happen not only at the inferior frontal area but also at the posterior brain.

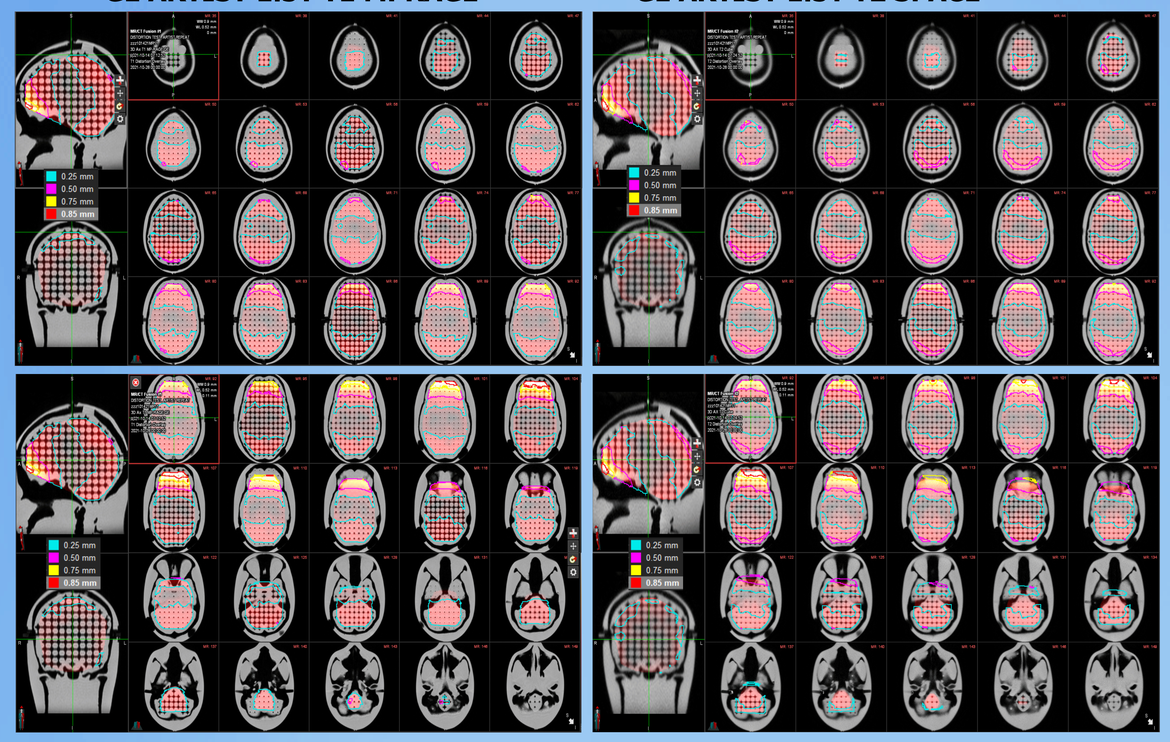
CONCLUSIONS

This evaluation helps us assess geometric uncertainties in the MR images used for target delineation and evaluate scanner performance. The magnitude of the geometry distortions of these three MRI scanners are acceptable for clinical radiosurgery. This distortion check should be performed routinely to assure high treatment quality.

OPC Skyra T1 MPRAGE **OPC Skyra T2 SPACE**



GE ARTIST 1.5T T1 MPRAGE **GE ARTIST 1.5T T2 SPACE**



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