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A Characterization of the Lap Aquarius Phantom of external lap laser alignment and MR Geometric distortion verification for the use of SRS patient simulation

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Purpose: Explore additional applications of LAP's Aquarius external laser alignment verification Phantom by examining geometric accuracy of magnetic resonance images commonly used for planning intracranial stereotactic radiation surgery (ICSRS) cases. Background: Accountability that the MR images of the brain contain no distortions within regions of interest is crucial during the treatment planning process. Pixel shifting during one of these artifacts in MRI can be several millimeters, which can negatively affect diagnosis and treatment of intracranial lesions. Reliability in ICSRS treatment planning will help prevent healthy tissue irradiation and improve dose conformity. Method: The scans were performed with MRI protocols used for ICSRS and head and neck diagnosis, and their images fused to computerized tomographic (CT) images. The geometric distortions (GDs) were measured against CT images in all axial, sagittal, and coronal directions at different levels. Findings: MR images of the Aquarius Phantom show a match between the nonlinearity along the z-axis crosshair and typical RF gradient nonlinearity along the frequency encoding gradient. There is linear correlation between MR divergence datasets of distorted crosshairs, and nonlinear correlation between MR divergence datasets of the distorted crosshair with the CT divergence datasets of the cross plane. GD up to about 2 mm are observed at the distal regions of the longitudinal axis. Discussion: Using the Aquarius Phantom, one is able to detect GD in ICSRS planning MRI acquisitions, and align the external LAP patient alignment lasers. Based on the results, one may recommend using the Aquarius Phantom to determine if margins should be included for ICSRS treatment planning.

A Characterization of the LAP Aquarius Phantom for External LAP Laser Alignment and MR Geometric Distortion Verification for the Use of SRS Patient Simulation

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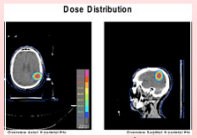
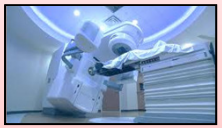
Introduction

- Accountability that the MR images of the brain contain no distortion is crucial during the treatment planning process. Pixel shifting during one of these artifacts in MRI can be several millimeters, which can negatively affect diagnosis and treatment of intracranial lesions.
- Reliability in ICSRS treatment planning will help prevent healthy tissue irradiation and improve dose conformity.



Stereotactic Radiation Surgery



SRS Patient Alignment, less than mm precision.

[1]

[2]

- Geometric distortion (GD) is an artifact caused by errors during the spatial encoding in MRI.
- Machine-induced, or patient-induced.

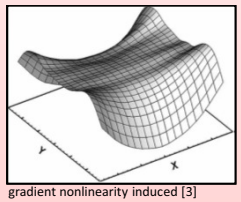
Purpose

To explore additional applications of LAP's Aquarius external laser alignment verification Phantom (Aq-LAP Phantom) by examining geometric accuracy of magnetic resonance images commonly used for planning intracranial stereotactic radiation surgery (ICSRS) cases.

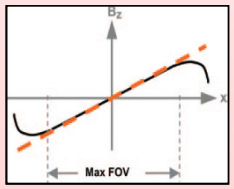
Methods

- Newly designed external patient alignment lasers first are aligned by the Aq-LAP Phantom at a Siemens Magneton Vario 3T MR unit.
- The scans are then performed with four different MR protocols which may be used for head and neck diagnosis and ICSRS with 4-1 mm temporal resolution, respectively.
- The MRI is then fused to 1 mm cut computerized tomography (CT) images acquired by a Siemens Somatom Sensation Open©.
- The GDs are measured against the CT in all axial, sagittal, and coronal directions at different levels.
- The F-test is then used to determine their statistical correlation.

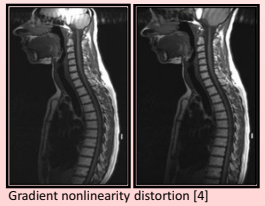
Results



gradient nonlinearity induced [3]



Gradient nonlinearity [4]

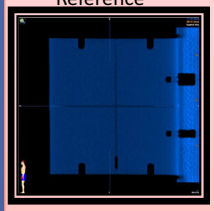


Gradient nonlinearity distortion [4]

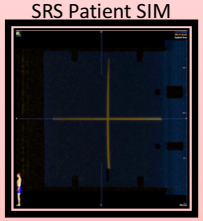
Chemical shift artifact [5]

Examples of geometric distortion (above)

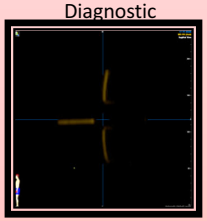
CT Reference



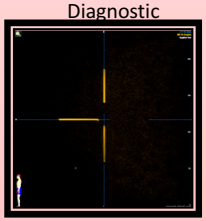
3D MPRAGE SRS Patient SIM



T2 Diffusion Axial Diagnostic



T2 Axial Diagnostic



T2 FLAIR Axial Diagnostic

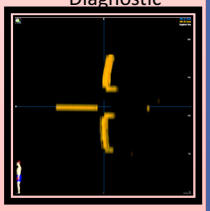


Table I: These statistics are ANOVA p-values comparing the divergence datasets of the diagnostic acquisitions with CT in axial view.

Axial View			
T1 Axial 3D MPRAGE	T2 FLAIR Axial	Diffusion Axial TRACE	T2 Axial
1.47E-56	1.59E-35	1.64E-31	3.03E-01

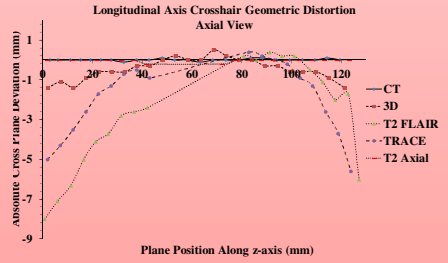


Figure 1: The geometrical deviations along the longitudinal axis crosshair have been plotted over 5 mm intervals from the head of the phantom distally toward its feet. As compared to the crosshair linearity in the CT image measurements, distinctive nonlinearity is seen in three out of the four MR acquisitions.

Table II: ANOVA p-vales comparing divergence datasets from Aquarius Phantom MR Scans using a twelve channel head coil in axial view

	T1 Axial 3D MPRAGE	T2 FLAIR Axial	Diffusion Axial TRACE	T2 Axial
CT	0.173	4.65E-04	4.68E-19	2.93E-03
3D MPRAGE	-	3.45E-06	6.51E-22	3.15E-05

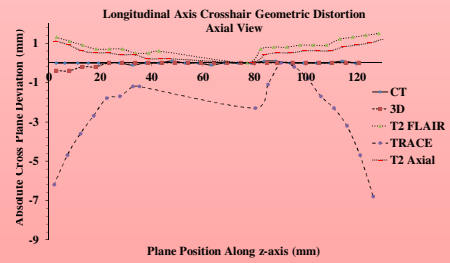


Figure 2: This time with a twelve channel head coil applied around the Aquarius Phantom, the comparison of the norm linearity (CT image measurements) with the nonlinearity seen in MR acquisitions appears to be distinctively different.

References

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Discussion

- The standard deviation (σ= ± 0.02 mm) from the CT divergence datasets is used to determine the margin of error that may occur during measurements.
- The MRI scans which did not utilized the head coil fulfilled external LAP laser alignment verification more successfully than did the scans that were done with the head coil.
- Based on table III, the repetition time TR appears to be directly proportional to the magnitude of distortion along the cross plane.
- Bowing of the cross plane in the MR images without the head coil suggested gradient field nonlinearity as the cause of the distortion.
- However, the head coil's transceiver antenna system may also increase the number of variables to consider as a cause of the artifact.
- Further investigation is needed to determine their cause.

Table III: MR acquisition time parameters (ms)

	3D MPRAGE	T2 FLAIR Axial	Diffusion Axial TRACE	T2 Axial
TR	1900	8000	6800	3500
TE	2.93	82	90	94
TI	9000	2370	-	-

Conclusions

- Using the Aquarius Phantom, one is able to detect GD in ICSRS planning MRI acquisitions, and align the external LAP patient alignment lasers.
- Based on the results, one may recommend using the Aquarius Phantom to determine if margins should be included for SRS treatment planning.

Acknowledgements

- LAP of America, LC, Boynton Beach, FL.
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