Assessment of residual MRI geometric distortions in brain and spine stereotactic treatments

Karima Tamsamani[1,2], Aurélie Tournier[1], Thomas Pulseux[2], Soleakhena Ken[1], Ramiro Moreno[2] and Laure Vieillevigne[1]
[1]Department of Medical Physics, Oncopole Claudius Regaud, Toulouse, France
[2]Spin Up, ALARA Group, Entzheim, France

Introduction

Stereotactic radiotherapy is an external radiotherapy technique that delivers high doses to target volumes while minimizing the dose received by organs at risk (OAR). CT images serve as the reference images for dose calculation in radiotherapy, but MRI images are often necessary to define target volumes due to their superior spatial resolution and soft tissue contrast. However, despite vendor distortion corrections, residual distortions may still be present and could affect the spatial representation of anatomical images [1].

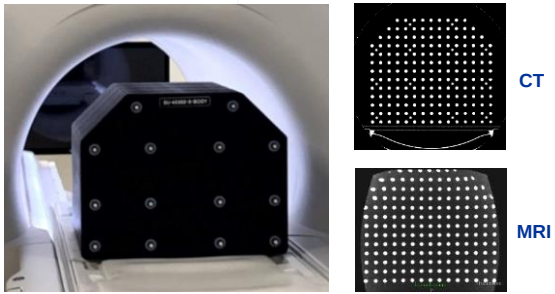


Figure 1. CT and MRI acquisitions of CARTESIAN 3D BODY phantom (www.spin-up.fr, ALARA Group, France)

Distortions can impact the contouring of target volumes and, consequently, the treatment plans, in particular for small targets. The aim of this study was to quantify residual gradient nonlinearity distortions for stereotactic treatments for brain and spine tumors and to evaluate their impact on dose distributions.

Materials and methods

The Cartesian3D BODY phantom (Figure 1) was utilized to measure residual geometric distortions for quality assurance and to generate corrected RTstruct contours. Distortion maps were obtained by comparing the centers of beads on the reference CT to their corresponding centers on MRI images acquired for the clinical sequences (T1 3D Gradient Echo for brain, T1/T2 3D SPACE for spine) and for a standard TFL 3D sequence.

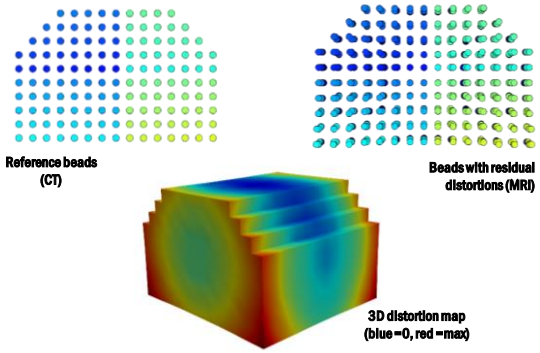


Figure 2. 3D MRI Distortion map = CT and MRI beads position differences

Twenty patients with multiple tumors located in the periphery of the brain, and five patients with spine tumors, were selected. Their MRI-contoured DICOM RTStructs were corrected by applying phantom-based 3D distortion maps (Figure 2) through the Spin Up CartesianRT software. Differences between structures before and after the correction of the distortion were evaluated using the Dice score and the Hausdorff distance (Figure 3).

Results

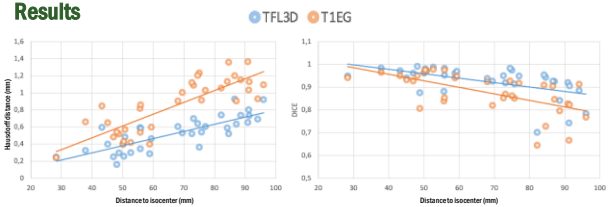


Figure 3. Hausdorff and DICE for brain tumors, taking into account TFL3D (standard) or T1EG (clinical) MRI sequences

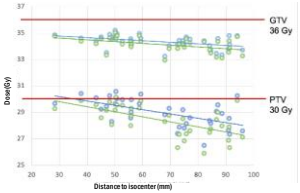


Figure 4. D98%, D99% for GTV and PTV as function of distance to isocenter, red lines represent clinical prescription

In the worst case for brain tumors, the Dice index and Hausdorff distance were approximately around 0.65 and 1.4 mm, respectively, when the distance from the magnet isocenter was 90 mm (Figure 3), resulting in dosimetric errors of around 10% (Figure 4). For spine tumors, distortion primarily affected the spinal cord due to its position at the edge of the field of view and its geometric shape.

Conclusion

Geometric distortions become a critical issue for structures located more than 6 cm from the magnet isocenter and can induce significant dosimetric impacts on target and OAR volumes. Therefore, MRI 3D distortion should be evaluated and taken into account during the treatment planning process and quality assurance program in radiotherapy.

[1] C. K. Glide-Hurst et al., « Task group 284 report: magnetic resonance imaging simulation in radiotherapy: considerations for clinical implementation, optimization, and quality assurance », Med. Phys., vol. 48, no 7, p. e636‑e670, juill. 2021, doi: 10.1002/mp.14695.