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Characterization of 3D spatial integrity on a 0.35T MR-LINAC

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Introduction

The MRIdian Linac (ViewRay, Ohio, USA) is a MR-guided radiotherapy system which combines a low field MR scanner (0.35T) with a radiotherapy gantry (6MV linac) located in the magnet split bore. The superior high soft tissue contrast of MRI compared to computed tomography is expected to improve tumor delineation as well as patient setup. However, the geometric accuracy that is crucial in radiation therapy to place the dose at the intended position, is limited by several hardware factors (magnetic field inhomogeneities, gradient non-linearity) as well as by sample related effects (susceptibility artefacts, chemical shift). This abstract aims at characterizing the 3D spatial integrity of the MR images at different gantry angles and for different offsets positions in the transverse plane.

Materials and Methods

We acquired images of the Large Field MRI Distortion Phantom (CIRS, Norfolk, USA) with the clinically bSSFP (balanced steady state free precession) sequence modified to cover a large field of view (FOV) of 32.4x35x35.2cm3 with a resolution of 1.048x1.048x1mm3.This phantom consists of a 3D grid (3mm rodes spaced by 20mm, submillimeter precision) distributed in a cylinder like structure (diameter 330mm, length 300mm) filled with water. Over the whole volume the grid vertices define 1885 control points. The phantom was imaged at four gantry angles (0°, 90°, 180° and 270°) and at four different shifts in the transverse plane. We implemented a program in Matlab (R2019a, The MathWorks, USA) to automatically detect the position of the vertices in the acquired volume inspired by the methodology presented by Jafar et al. [1]. This software relies on a pattern matching approach combined with a connected component algorithm. The set of vertices representing the phantom was rigidly registered to the theoretical locations of the vertices to correct for small rotations and translations in the phantom setup. Spatial integrity is assessed by measuring the Euclidian distance of the detected vertices to their theoretical locations. Manual post-processing was done in order to remove markers located in corrupted image region (especially due to bSSFP banding artifact).

Results

The passing rate specified by the vendor are 1mm and 2mm within a 100mm and 175mm radius from the isocenter, respectively. The maximum displacement distances measured for each configuration (table 1) respect these constraints except for the 0° gantry angle configuration. However, the average distortion for this setup is 0.44mm. Ginn et al. [2] reports similar results for the Cobalt-60 MRIdian model. There was no change in distortion when the phantom was shifted +/-40mm in the transverse plane.

Conclusions

The specification defined by the vendor are met and could be assessed simultaneously in three dimensions for different clinically relevant setups. Patient positioning can be performed off-axis without increased distortions.

References:

1. Jafar, M., et al., Assessment of Geometric Distortion in Six Clinical Scanners Using a 3D-Printed Grid Phantom. 2017. 3(3): p. 28.

2. Ginn, J.S., et al., Characterization of spatial distortion in a 0.35 T MRI-guided radiotherapy system. Physics in Medicine & Biology, 2017. 62(11): p. 4525.

Primary authors: Dr POUYMAYOU, Bertrand (Radiation Oncology Department, Universitätsspital Zürich, Switzerland); Ms ROHRER, Jana (Radiation Oncology Department, Universitätsspital Zürich, Switzerland); Prof. UNKELBACH, Jan (Radiation Oncology Department, Universitätsspital Zürich, Switzerland); Prof. ANDRATSCHKE, Nicolaus (Radiation Oncology Department, Universitätsspital Zürich, Switzerland); Prof. GUCKENBERGER, Matthias (Radiation Oncology Department, Universitätsspital Zürich, Switzerland); Dr TANADINI-LANG, Stephanie (Radiation Oncology Department, Universitätsspital Zürich, Switzerland); Dr WILKE, Lotte (Radiation Oncology Department, Universitätsspital Zürich, Switzerland)

Presenter: Dr POUYMAYOU, Bertrand (Radiation Oncology Department, Universitätsspital Zürich, Switzerland)

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