PROTON CT FOR PRETREATMENT POSITIONING VERIFICATION

Roberto Cassetta[1], P Piersimoni[2], V Giacometti[3], R Schulte[4], M Riboldi[1], R Johnson[5], C Ordonez[6], G Baroni[1], V Bashkirov[4], G Coutrakon[6]

[1] *Politecnico di Milano, Milan, Italy.*

[2] *German Cancer Research Center, Heidelberg, Germany.*

[3] *University of Wollongong, Wollongong, Australia.*

[4] *Loma Linda University, Loma Linda, USA.*

[5] *UC Santa Cruz, Santa Cruz, USA.*

[6] *Northern Illinois University, DeKalb, USA.*

Introduction: The number of proton therapy centers is increasing due to its potential for superior dose conformation with improved tumor control and reduced treatment side effects. However, the benefits of proton therapy may be compromised by uncertainties in treatment planning (conversion of Hounsfield units to relative stopping power or RSP) and patient positioning at the time of treatment. This could lead to over-dosing normal tissues and under-dosing tumor. Therefore, a treatment planning/image guidance system for proton therapy that acquires accurate RSP values with low-dose (< 2 mGy) is desirable. Proton CT (pCT), i.e., imaging with protons, promises to have these features.

This study tested a 3D registration algorithm for pCT-based image registration in a realistic pediatric head phantom. An experimental proton CT scan of the phantom (reference) was transformed by random 3D errors with 6 degrees of freedom (DOF) and the algorithm was used to correct the mismatch between reference and transformed images.

Methods: Ninety projections of a pediatric head phantom (model 715-HN, CIRS) were acquired with the phase II Proton CT Scanner built by the U.S. pCT Collaboration and reconstructed into a 3D DICOM image (fig. 1) with a voxel size of 0.58 mm, 0.58 mm and 1.25 mm for x, y and z respectively. The reconstruction was performed using a filtered back projection (FBP) algorithm as the initial step followed by 5 iterations of the TVS-DROP iterative reconstruction method. A 3D registration algorithm was developed based on the Insight Segmentation and Registration Toolkit ITK library; Mattes mutual information was used as the similarity metric and the '*Regular Step Gradient Descent Optimizer'* as the optimizer. To evaluate the image registration algorithm, 10 random transformations with 6 DOF (translation and rotation) were generated by orthogonal sampling and applied to the FBP-only pCT image (fastest acquisition). The applied transformations were inside a clinically observed range of ±3 mm for translations and ±5 degrees for rotations. Thus, the described steps allowed the simulation of 10 random setup misalignments. After pairwise registration of reference and transformed images, the difference between reference transforms and the suggested corrections (residual errors) were obtained and analyzed.

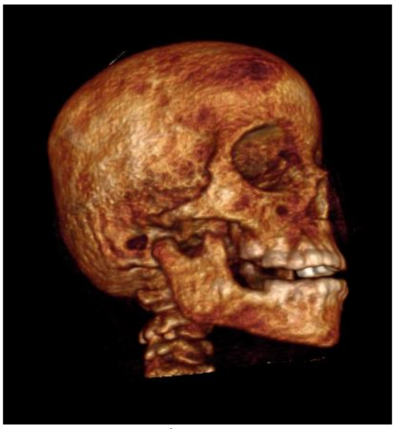

Figure 1.

Results: The residual translation (T) and rotation (R) errors after the image registration procedures for the 10 random misalignments as mean and standard deviations are presented for x, y and z axis: Tx = 0,114 ± 0,185 (mm), Ty = -0,181 ± 0,135 (mm), Tz = -0,181 ± 0,135 (mm), Rx = 0,084 ± 0,084 (deg), Ry = 0,042 ± 0,099 (deg), Rz = -0,003 ± 0,129 (deg).

Conclusion: A rigid image registration algorithm was tested within the context of proton CT to proton CT evaluation for image-guided patient positioning in proton therapy. Residual translational errors were found to be sub-voxel size and rotation errors were less than 0.1 deg. Because proton CT gives much less dose to the patient compared to a CBCT (of the order of 1-2 mGy or less), it may be used on a daily basis not only for accurate positioning but also for replanning and adaptation purposes, reducing range errors and allowing reduced treatment planning margins.