AbstractID: 3394 Title: Improved dose accuracy for on-line adaptive radiation therapy using deformable dose registration

Purpose: The time available for dose evaluation in daily on-line adaptive radiotherapy scenarios necessitates the use of fast correction-based algorithms such as pencil beam (PB) algorithms, but precludes the use of accurate Monte Carlo (MC) algorithms. This study proposes to improve PB dose accuracy by utilizing deformable image registration techniques in a process called deformable dose registration (DDR): MC results on a deformed patient anatomy are approximated based on an MC calculation on a reference anatomy and the deformation field of the PB calculations between the reference and current anatomies.

Method and Materials: A 5×5 cm^2 6-MV AP beam incident upon a thoracic CT image set $I_0(\mathbf{x})$ was computed with both PB and MC dose-calculation algorithms resulting in $D_0^{PB}(\mathbf{x})$ and $D_0^{MC}(\mathbf{x})$. A thoracic case was chosen because of known inaccuracies in the radiological path-length correction of PBs for lung heterogeneities. The same treatment beam was then computed on a deformed data set, $I_1(\mathbf{x})$, to obtain $D_1^{PB}(\mathbf{x})$ and $D_1^{MC}(\mathbf{x})$. Treating $D_0^{PB}(\mathbf{x})$ and $D_1^{PB}(\mathbf{x})$ as images, the (Discrete Cosine Transform) DDR operator $\overline{\mathbf{U}}_{0\to1}(\mathbf{x})$ was determined that transformed $D_0^{PB}(\mathbf{x})$ to $D_1^{PB}(\mathbf{x})$, $D_1^{PB}(\mathbf{x}) = D_0^{PB}(\overline{\mathbf{U}}_{0\to1}(\mathbf{x}))$. $D_0^{MC}(\mathbf{x})$ was then transformed to $I_1(\mathbf{x})$ using $D_0^{MC}(\overline{\mathbf{U}}_{0\to1}(\mathbf{x})) = \hat{D}_1^{MC}(\mathbf{x})$ ($\wedge$ indicates an estimated dose distribution). Dose distributions were compared to determine if $D_1^{PB}(\mathbf{x})$ or $\hat{D}_1^{MC}(\mathbf{x})$ better predicts $D_1^{MC}(\mathbf{x})$ based upon isodose contours, dose differences, distance-to-agreement, and gamma-analysis.

Results: Isodoses for $\hat{D}_1^{MC}(\mathbf{x})$ better predicted $D_1^{MC}(\mathbf{x})$ than those from $D_1^{PB}(\mathbf{x})$. The mean dose difference for $\hat{D}_1^{MC}(\mathbf{x})$ is zero, while for $D_1^{PB}(\mathbf{x})$ it is ~-3%. Using a 3%, 3 mm criteria, 70% of $D_1^{PB}(\mathbf{x})$ agreed with $D_1^{MC}(\mathbf{x})$ with $\gamma < 1.0$, while 92% of $\hat{D}_1^{MC}(\mathbf{x})$ had $\gamma < 1.0$ indicating that $\hat{D}_1^{MC}(\mathbf{x})$ is a better predictor of $D_1^{MC}(\mathbf{x})$ than $D_1^{PB}(\mathbf{x})$.

Conclusion: Using DDR techniques with fast PB results to estimate a more accurate algorithm's dose improves overall dose accuracy compared with using the fast PB algorithm alone. Such techniques may be useful in on-line adaptive radiotherapy scenarios where dose accuracy is required, but dose calculation time is limited. (Work supported by NIH-R01-CA98524)