Simulation-free adaptive MR guided workflow for single visit palliative radiotherapy: development of a dedicated CT atlas

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Résumé

Introduction: Simulation-free radiotherapy reduces palliative workflow duration by relying on recent diagnostic CT scans. By leveraging MR-linac adaptive capabilities, we aim to reduce consultation-to-treatment time to under three hours, enabling a single-visit pathway. Conventional simulation imaging and patient-specific planning are therefore omitted and replaced with generic data. Generic plans are adapted using daily MR images and a deformed generic CT for dose calculation. This work presents the construction of a generic pelvic CT atlas from which an assignment algorithm selects the CT best matching the patient's anatomy and gray-level intensities.

Material and methods: Using 221 pelvic CT scans, 4 shape and 3 intensity features were extracted. Several clustering algorithms (e.g., GMM, HAC) were evaluated by maximizing clustering metrics such as silhouette score. Final clusters were obtained by combining the shape- and intensity-based groups. For each cluster, a representative generic CT was generated using an iterative registration-based averaging approach. Dose planning was performed using the ViewRay MRIdian TPS, leveraging built-in tools to register CT scans to MRI.

Results: Shape-based clustering yielded 4 clusters (silhouette score=0.32) driven by body volume and adipose tissue distribution. Intensity-based clustering yielded 2 clusters (silhouette score=0.42) mainly reflecting differences in bone density. Both feature sets were significantly correlated with patient BMI (shape: p=2.6 × 10-29; intensity: p=1.9 × 10-3). A trend toward correlation was observed between intensity-based clusters and patient age

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(p=0.06), despite limited age variability in the database. Combining features resulted in 8 distinct final clusters. Initial validation compared patient CT scans with their corresponding generic CTs; both registered to the patient's MRI. Overall agreement was high (SSIM=0.88; MAE=60 HU). However, limitations were observed in bone registration for generic CTs (Dice=0.74; MAE=199 HU). Despite this, preliminary dose comparisons showed excellent agreement. Using a 1%/1mm gamma criterion, the local gamma pass rate was 97.21%. The difference in mean dose to the CTV (iliac location) was -0.033 Gy for a 8 Gy prescription.
Conclusions: This pipeline defined 8 clinically interpretable anatomical phenotypes and generated generic pelvic CT scans. Despite limitations in bone registration, initial dose comparison results demonstrate the robustness of the approach. The use of generic CTs enables omission of conventional simulation imaging while maintaining high dosimetry accuracy in palliative radiotherapy. Further validation across multiple pelvic sites and all clusters is required prior to clinical implementation. An automated generic CT assignment algorithm is currently under development. Workflow efficiency gains and improvements in patient experience will ultimately be assessed in a comparative clinical trial.

Mots-Clés: Simulation free, adaptive RT, MR linac, Atlas based planning