Evaluation of Automated Tumor Delineation via Deformable Image Registration for Adaptive Radiotherapy

Radiation Oncology
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Purpose

The Radiation Medicine Program at Princess Margaret Cancer Centre is implementing an online adaptive radiotherapy (ART) technique based on MRI for patients with liver cancer.

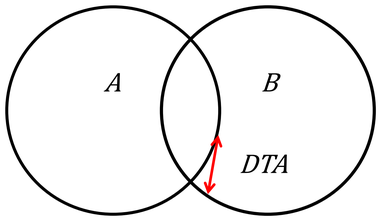
- Delineating the gross tumor volume (GTV) on MRI each day is time consuming, therefore an automated approached would make ART more feasible.
- Image registration is the process of calculating a geometric transformation to anatomically relate and align two image series.[1]
- **Deformable image registration (DIR) can potentially map a previous GTV delineation to a daily MR image automatically. However, the accuracy of this technique needs to be investigated.**

Methods

- 10 patients with liver cancer in this Research Ethics Board (REB) approved imaging study for T2-weighted MR were imaged 4 to 5 times during radiation treatment using a 3.0 T Siemens Verio scanner with a slice thickness of 5 mm.
- The GTV(s) and liver were contoured on all images by a Radiation Oncologist in a radiation treatment planning system (RayStation v6.1, RaySearch Laboratories, Sweden).
- Rigid and deformable image registration was performed to map the GTV from the first planning MR and CT image (reference) to subsequent MR images (target). Rigid registration was gray level based with a focus on the liver ROI (region of interest). Four deformable registration algorithms were compared:
  - Intensities only (using image grey values)
  - Intensities and Liver ROI
  - Liver ROI only
  - Biomechanical (MORFEUS)
- Deformable image registration was also performed in a different treatment planning system (Monaco v5.1, Elekta, Sweden).

Accuracy Evaluation Metrics

- Dice similarity coefficient (DSC) and distance-to-agreement (DTA) metrics were used to assess accuracy of deformed GTVs.
- DSC is a spatial volume overlap index of two contours; a value of 1 is perfect overlap and a value of 0 is no overlap.
- Mean DTA is the average of the distances between each voxel on contour A's surface and the closest voxel on contour B's surface.
- Acceptable values for DSC are 0.8-0.9; acceptable values for mean DTA are within the maximum voxel dimension (~2-3 mm).[1]



$$DSC(A,B) = \frac{2|A \cap B|}{|A| + |B|}$$

Deformable Image Registration

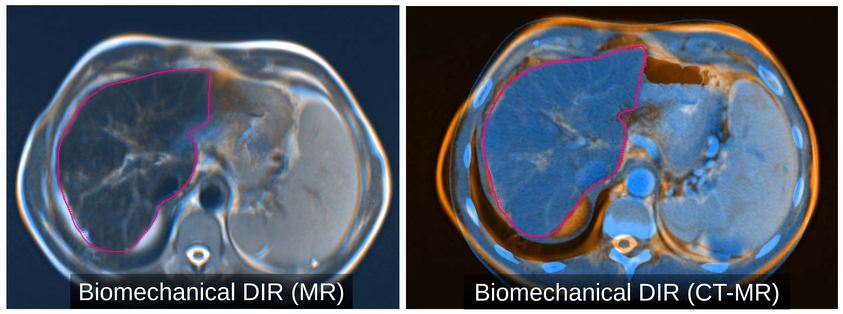


Figure 1. Fusion of biomechanical DIR for MR and CT-MR with the reference (blue) and target (orange) images. The pink contour is the liver ROI with the solid contour on the reference image and the dashed contour on the target image.

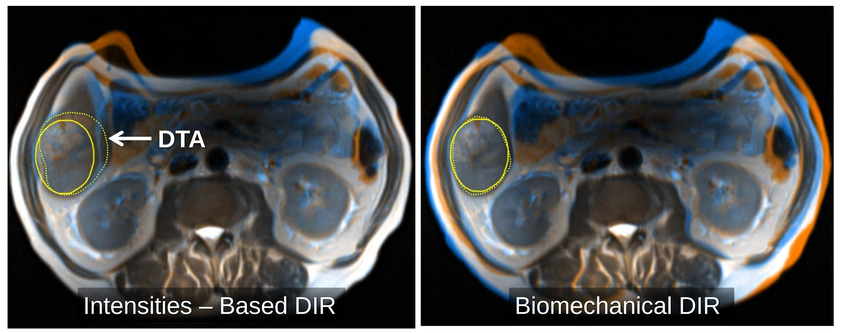


Figure 2. Deformed GTVs on Intensities-based DIR (left) and biomechanical DIR (right) for MR. The solid yellow contour is on the reference image (blue) and the dashed yellow contour is on the target image (orange).

Results I

Accuracy of Tumor Volume Overlap for Image Registrations

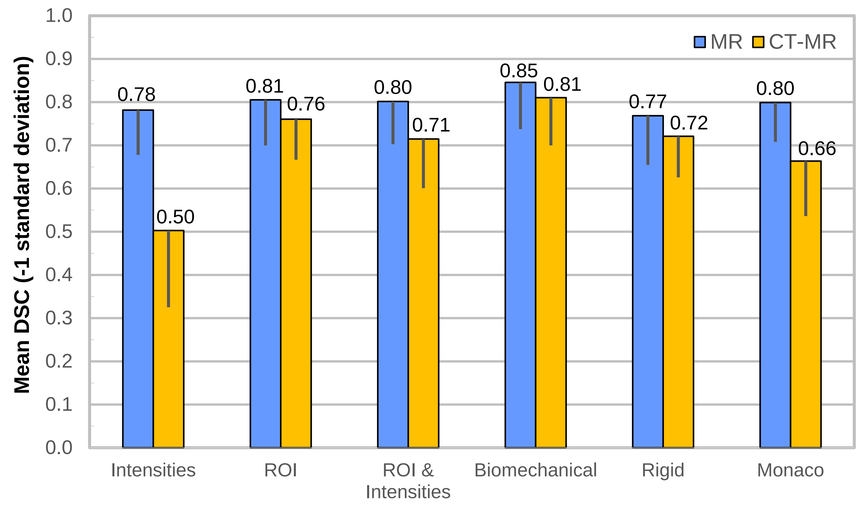


Figure 3. Mean DSCs for deformed GTVs and GTVs delineated by a Radiation Oncologist for MR and CT-MR registrations (*n = 57*).

Results II

Accuracy of Tumor Surface Geometry for Image Registrations

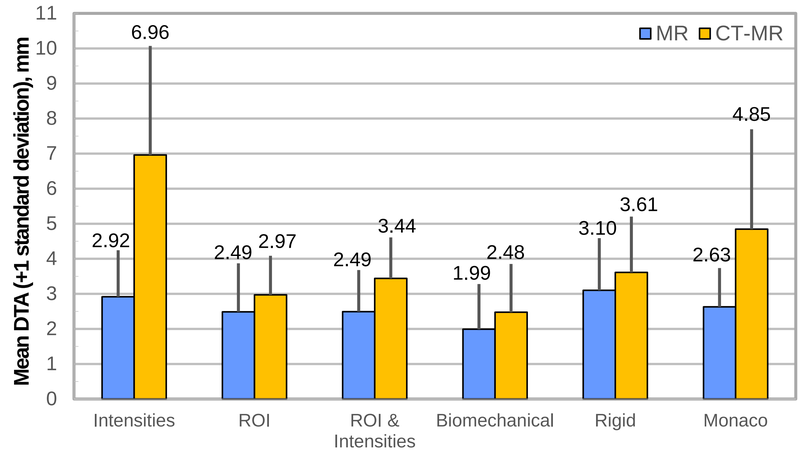


Figure 4. Mean DTAs to measure surface accuracy for deformed GTVs and GTVs delineated by a Radiation Oncologist for MR and CT-MR registrations (*n = 57*).

Discussion

- Biomechanical DIR was the most accurate for both MR and CT-MR as it met the prespecified accuracy for mean DSC and DTA.
- Monaco's DIR was more accurate for both MR and CT-MR compared to Intensities-based DIR due to the algorithm being less constrained.
- Intensities-based DIR was found to be comparable to rigid registration for MR despite MR's excellent soft tissue contrast; variation in image gray values across the target images may be a source of error.
- A previous study[2] found ROI based DIR to have the smallest mean DTA for liver ROI in MR and CT-MR. It also found biomechanical DIR to have the highest mean DTA after rigid registration for both liver MR and liver CT-MR.
  - However, biomechanical DIR also produced the best results for internal liver ROI accuracy for both MR and CT-MR
- Results for MR registrations suggest that compared to CT-MR, MR DIRs are not as sensitive to the algorithm used
- ***Next Steps:*** Using points of interest (POIs) near the GTV, assessing the internal accuracy of the liver ROI for DIRs.

Conclusions

- **This study validates an MR-only workflow with biomechanical image registration for accurately propagating a previous gross tumor volume delineation for online adaptive radiotherapy.**

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- ***References:***

- [1]Brock et al. *Medical Physics*, 2017 July; 44(7): e43-e47.
- [2]Velec et al. *Medical Physics,* 2017 July; 44(7): 3407-3417