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

Radiation Oncology
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Purpose

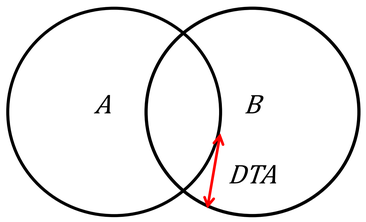
- The Radiation Medicine Program at Princess Margaret Cancer Centre is implementing an online adaptive radiotherapy (ART) technique based on MRI for patients with liver cancer.
- Delineating the gross tumor volume (GTV) on MRI each day is time consuming, therefore an automated approached would make ART more feasible.
- Image registration is the process of calculating a geometric transformation to relate and align two image series
- **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 GTVs and livers 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 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*)

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 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

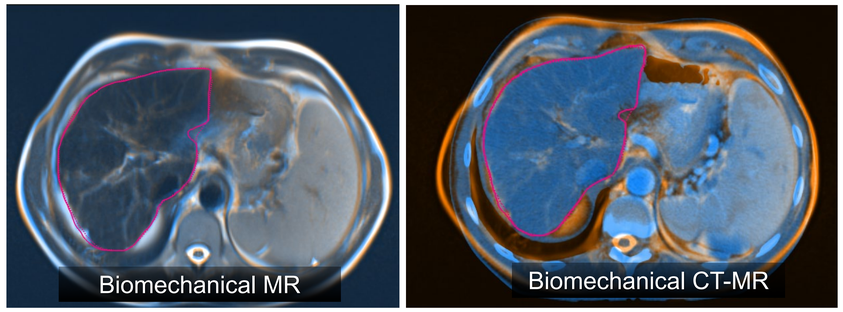


Figure 1. Fusion of biomechanical DIR for MR and CT-MR with the reference (blue) and target (orange) images. The pink contour is the liver ROI with the solid contour on the reference image and the dashed contour on the target image.

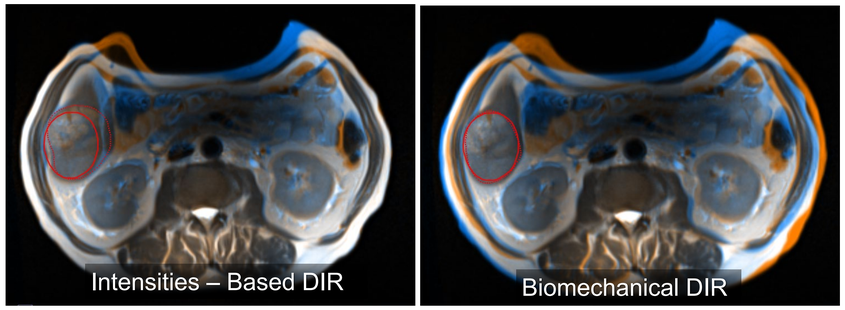


Figure 2. Deformed GTVs on Intensities-based DIR (left) and biomechanical DIR (right) for MR. Solid contours are on the reference image (blue) and dashed contours are on the target image (orange).

Results I

Volume Overlap for Rigid and Deformable Registrations

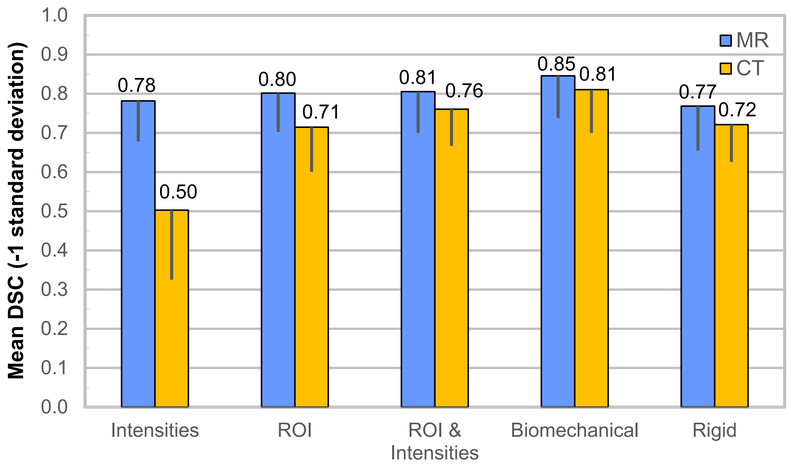


Figure 3. Mean DSCs for deformed GTVs and GTVs delineated by a Radiation Oncologist for MR and CT-MR registrations (*n = 57*).

Results II

Residual Surface Distances for Rigid and Deformable Registrations

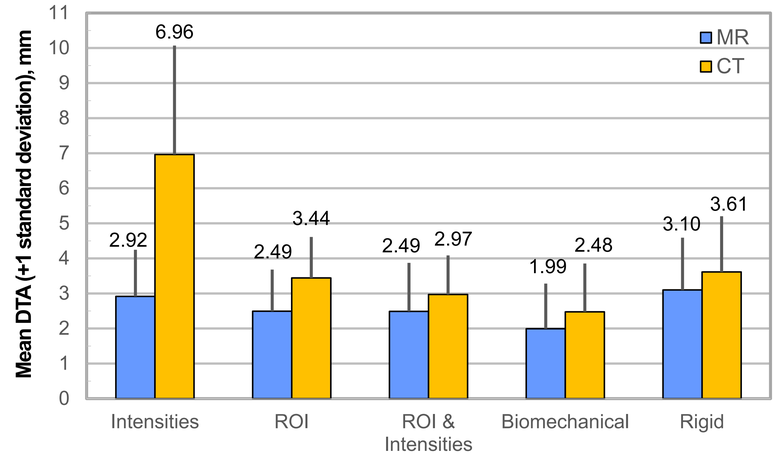


Figure 4. Mean DTAs to measure surface accuracy for deformed GTVs and GTVs delineated by a Radiation Oncologist for MR and CT-MR registrations (*n = 57*).

Discussion

- Biomechanical DIR was the most accurate for MR and CT-MR as it met the prespecified accuracy for mean DSC and DTA.
- ROI & Intensities-based DIR was the second most accurate for both MR and CT-MR despite being not recommended by RayStation for CT-MR due to its mono-modality similarity metric.
- Intensities-based DIR was found to be comparable to rigid registration for MR registrations despite MR's excellent soft tissue contrast. The DIR was the most inaccurate for CT-MR.
- 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.
- Mean DSC and DTA results for Intensities based DIR (MR) suggest that variation in image gray values across the secondary images may be a source of error for DIR.
- ***Next Steps:*** Validate current results against DIR results from a different treatment planning system (Monaco v5.1, Elekta, Sweden).

Conclusion

- **This study validates an MR-only workflow for improving the accuracy of automatic tumor delineation when compared to CT-MR.**
- ***Acknowledgements:*** Thank you to Dr. Jelena Lukovic for contouring the tumours and Dr. Laura Dawson for allowing us to participate in this research study.
- ***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