Robustness and Benefits of Longitudinal Image Co-Registration for Prediction of Triple Negative Breast Cancer Response to Neoadjuvant Chemoimmunotherapy

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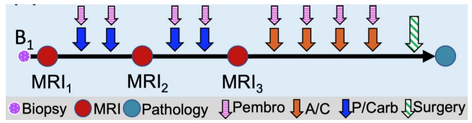
Goal

To establish a co-registration pipeline that achieves robust alignment of multiparametric breast MRIs acquired at multiple visits, improving accuracy in assessment of triple negative breast cancer (TNBC) response to neoadjuvant chemoimmunotherapy (NACI).

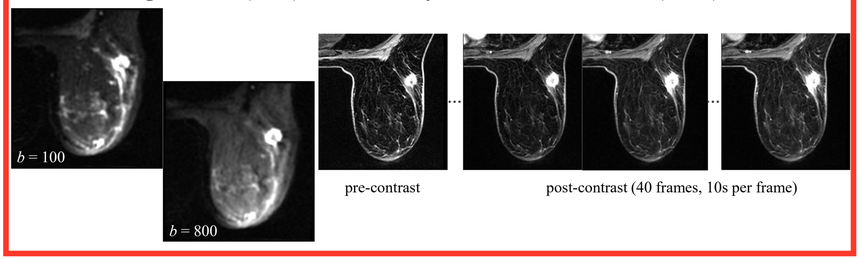
Patient Data

- Breast Cancer Moon Shot Program, MD Anderson Cancer Center
- Women (n = 29) with biopsy-confirmed TNBC enrolled in the ARTEMIS trial (NCT02276443)



Multi-parametric MRI

Diffusion-weighted MRI (DWI) **Dynamic contrast-enhanced (DCE-) MRI**



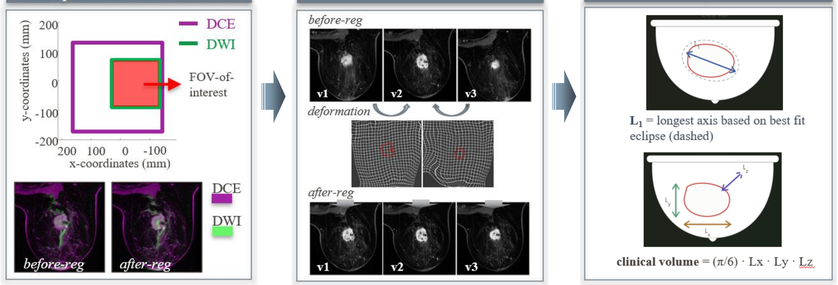
Methods

- Tumor contours were segmented by two radiologists. Imaging data were processed through our longitudinal analysis pipeline (Jarrett et al. Nature Protocols 2021). Intra-visit rigid co-registration was first performed to account for patient motion and misalignment between DCE- and DWI-MRI. Afterwards, inter-visit co-registration used b-spline nonrigid registration with a rigidity penalty on the tumor region.
- Investigated whether longitudinal registration improved the prognostic value of the "longest-axis" and "clinical volume" (calculated from the axis lengths of tumor in 3 dimensions), quantified by ROC AUC for differentiating pCR status using pre versus post co-registration measures.

Pre-processing
- Grid co-alignment
- Intra-visit registration across DCE time series
- Intra-visit registration between multi-parametric MRI

Inter-visit registration
- Non-rigid registration on whole breast tissue
- Rigid penalty to preserve tumor size and shape

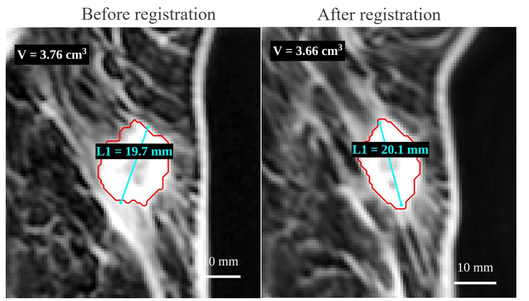
Post-processing
- Segmentation of breast
- Calculate quantities-of-interest: "clinical volume" and longest-axis dimension before and after inter-visit co-registration

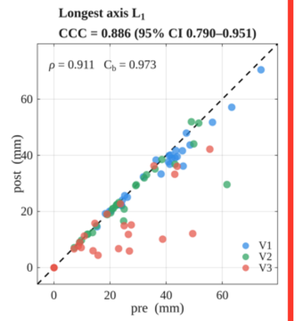


Jarrett et al., *Nature Protocol*, 2021

Results

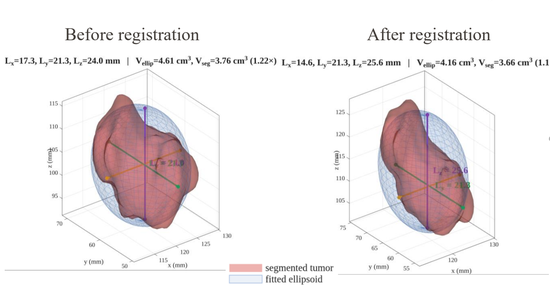
Longest-axis Analysis

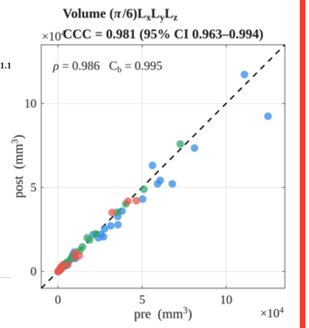




ROC analysis using the longest axis yielded AUC of **0.805** pre-coregistration and **0.831** post-coregistration.

"Clinical Volume" Analysis

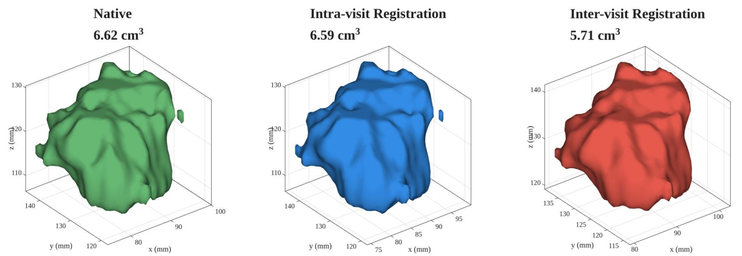


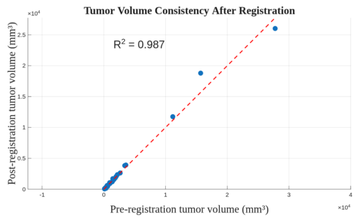


Clinical tumor volume ROC analysis yielded AUC of **0.733** pre-coregistration and **0.749** post-coregistration. Both indicated improvement in prediction power.

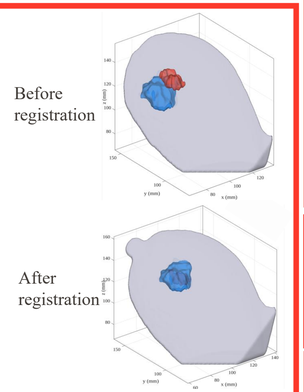
Tumor volume consistency as validation

Example of tumor volume preservation through pipeline





Inter-visit registration
$R^2 = 0.987$



We calculated the tumor volume to confirm pipeline robustness in preserving 3D tumor morphology, evaluated by concordance correlation coefficient (CCC) between the pre and post co-registration "delineated tumor volumes". Tumor volumes were well preserved, with CCC of 98.7% after co-registration

Conclusions

Our framework effectively retains the tumor's structural characteristics while correcting orientation bias and improving tumor progression assessment. Ongoing efforts include employing a larger cohort and performing habitat analyses.

Acknowledgement

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