

Brain-Dynamics: A Unified Platform for Longitudinal Tracking and Quantitative Assessment of Brain Lesion Dynamics in Neuroimaging

Mingli Chen,¹ Gregory Szalkowski,² Riya Prashad,² Jason S. Fernandes,² Fred, C. Lam,³ Cynthia Chuang,² Lei Wang,² Lianli Liu,² Qingying Wang,¹ Yinheng Zhu,¹ Scott G. Soltys,² Erqi L. Pollom,² Elham Rahimy,² David J. Park,² Yusuke S. Hori,² Robert Timmerman,¹ Tu Dan,¹ Zabi Wardak,¹ Michael Dohopolski,¹ Jill De Vis,¹ Jie Deng,¹ Hao Jiang,¹ Xuejun Gu,² Weiguo Lu¹
¹University of Texas Southwestern Medical Center, ²Stanford University

PURPOSE

To address fragmentation and variability in longitudinal brain lesion assessment, we developed Brain-Dynamics, a vendor-neutral platform integrating auto-segmentation, multimodal co-registration, lesion labeling/tracking, and quantitative analytics for research and clinical use.

METHOD

- Brain-Dynamics connects to PACS/EHRs, supports MRI/CT image analysis across timepoints, enables interactive contour editing, and exports DICOM for clinical integration (Figure 1).
- Three AI-based auto-segmentation models were built on nnU-Net and trained/validated on retrospective stereotactic images acquired from vestibular schwannomas (VS), brain metastases (BMs), and glioma patients, respectively.
- Using the Montreal Neurological Institute (MNI) space as a standard atlas, multimodal images are rigidly co-registered via mutual information (MI) and lesions names are standardized with their laterality and lobes.
- The platform supports quantitative measurements, including volume, three principal diameters, BMs velocity and multimodality radiomic analysis.

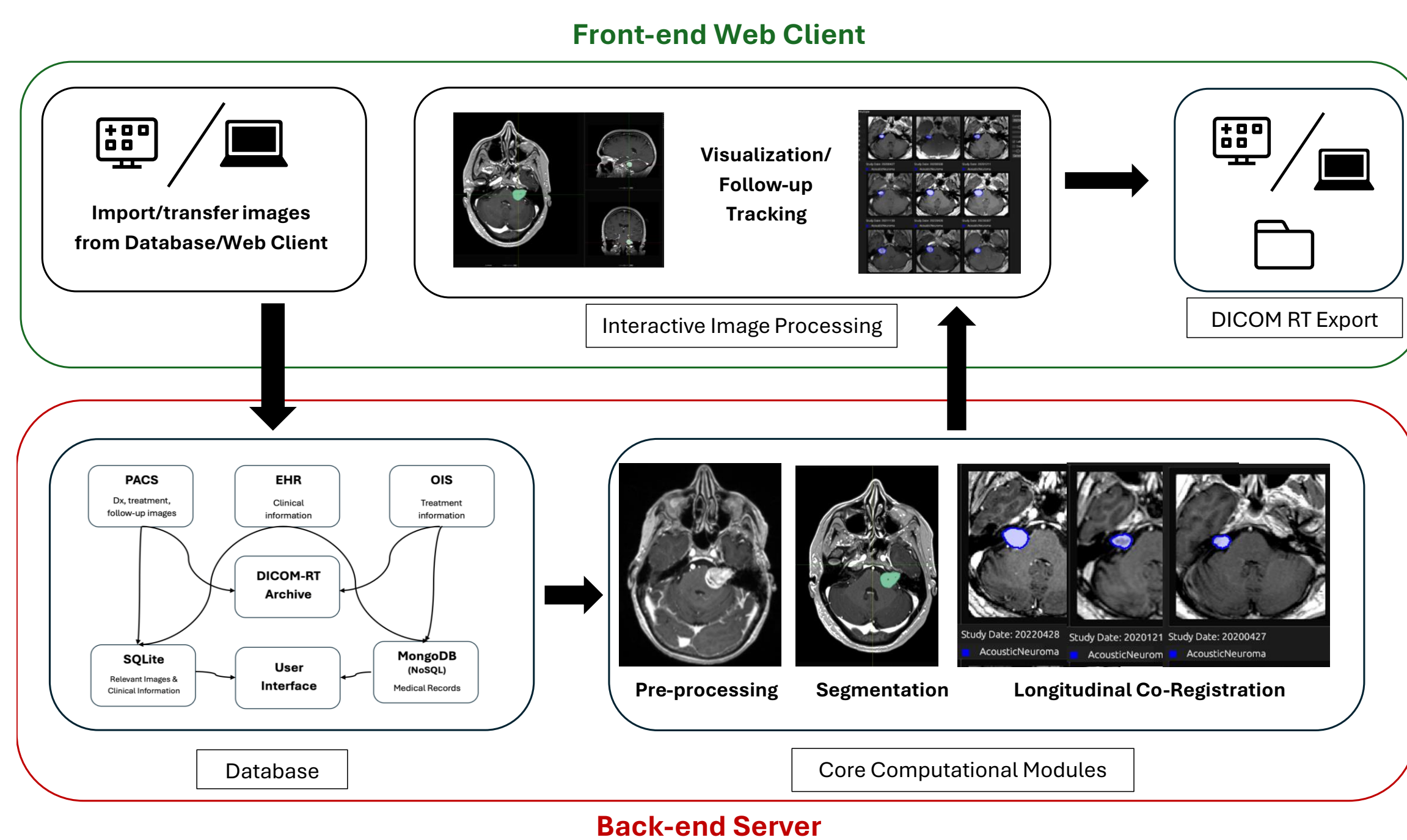


Figure 1 Brain-Dynamics platform consists of a front-end web client and a back-end server. The web client facilitate user interaction with database access, image visualization, and task selection. The back-end executes tasks, such as auto-segmentation, image co-registration, lesion tracking/analysis.

RESULTS

Brain-Dynamics' performance was evaluated on the accuracy of lesion detection, segmentation, and labelling.

- VS segmentation evaluated on 20 patients achieved Dice of 0.90 ± 0.05 , MSSD 0.19 ± 0.26 mm, and HD95 0.74 ± 0.57 mm, approaching inter-observer variability (Figure 2(a), (b)).
- Longitudinal VS volume tracking showed a pattern of post-SRS effects: transient enlargement due to treatment-related edema followed by stabilization or shrinkage (Figure 2(c)).

RESULTS (CONTINUED)

- BMs detection and segmentation evaluated on 79 patients with a total of 536 lesions achieved sensitivity of $89.70 \pm 1.85\%$, precision of $97.34 \pm 0.77\%$, Dice of 0.92 ± 0.06 , and lesion labelling accuracy of 100% (Figure 2 (d)).
- BMs tracking, including volume, orthogonal axis dimensions, and velocity, can be used to facilitate BMs re-SRS studies (Figure 2 (e)).
- Glioma segmentation on 840 image sessions (T1c+FLAIR) achieved Dice of 0.77 ± 0.29 , 0.84 ± 0.23 , and 0.86 ± 0.12 for tumor core, enhancing tumor, and edema, respectively, despite large heterogeneity in tumor shapes and intensities.
- The segmented substructures were used to facilitate studies of their morphological relationship and progression.

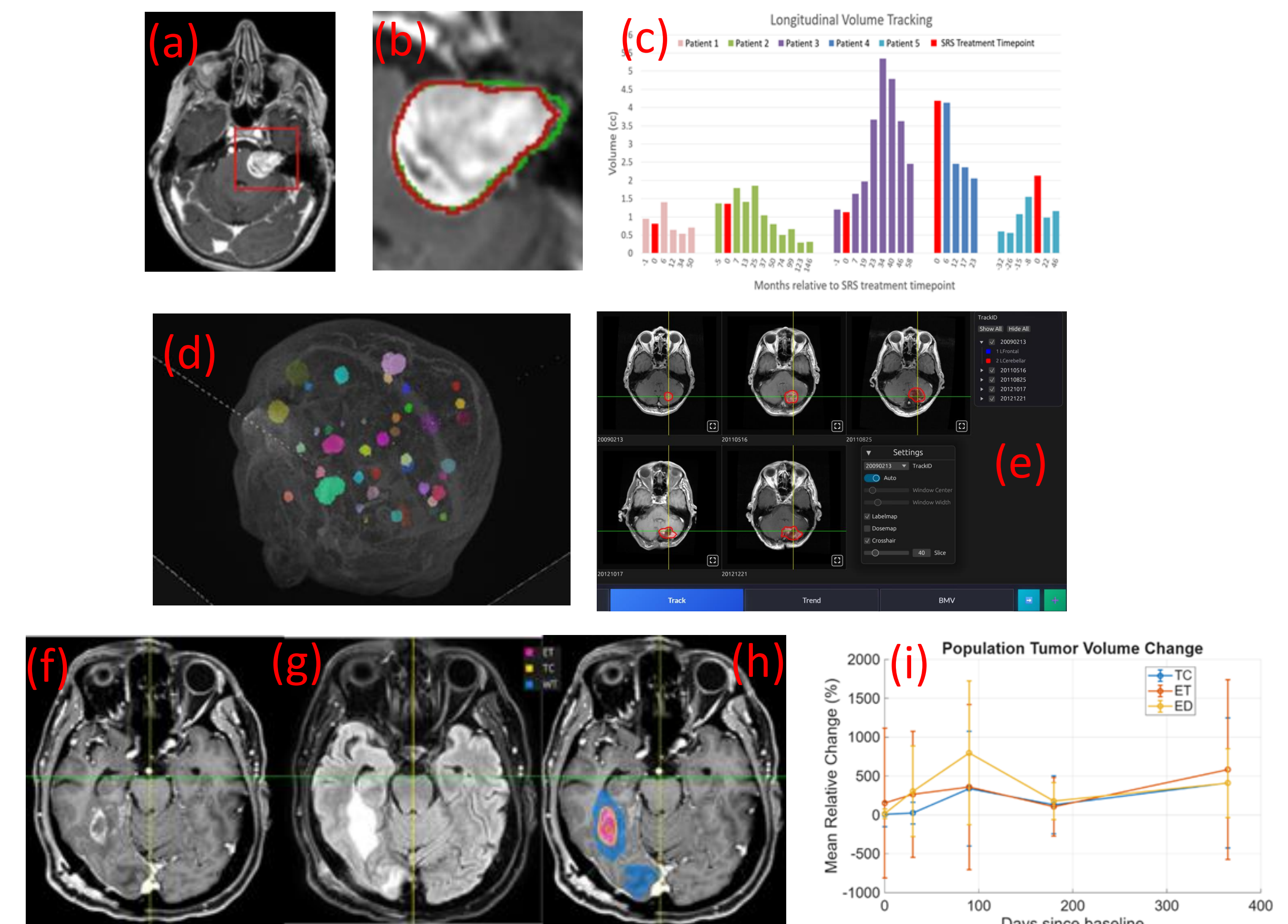


Figure 2 Quantitative results on 20 VS patients, 79 BMs patients and 210 Glioma patients with 840 image session. (a) & (b) Example of VS segmentation. Red: ground truth. Green: auto-segmentation. (c) Volume tracking for 5 VS patients. (d) Example of BM segmentation. (e) Co-registered images showing BM changes over time. (f) T1c and (g) FLAIR of a glioma patient. (h) Structure segmentation based on (f) and (g), including tumor core, enhancing tumor and peritumoral edema. (i) Population glioma tumor volume change.

CONCLUSION

Brain-Dynamics, a unified platform supports AI auto-segmentation with longitudinal lesion tracking and analysis on three brain diseases. Future work will expand the platform's application to other brain indications and prospectively evaluate its impact on clinic workflow and treatment decision making.