Iterative Improvement of PACS-Integrated AI Algorithm for Automatic Brain Metastasis Detection and 3D Segmentation

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Background/Problem Being Solved

Accurate detection and segmentation of brain metastases (BM) are pivotal for diagnosing, treating, and surveilling patients with BM. Nevertheless, manual lesion measurement is time-consuming. In this study, we iteratively improved the performance of a deep learning-based algorithm (Model 1-3, M1-3) for BM detection and 3D segmentation by leveraging a research instance of our PACS that streamlines continual learning and clinician-in-the-loop feedback.

Intervention(s)

In this retrospective single-center study, 156 pre- and post-Gamma Knife radiosurgery (GKR) MRI studies of patients with BM were de-identified and sent from clinical production to a research instance of our PACS (AI Accelerator, AIA, Visage Imaging, Inc.). Reference standard 3D BM segmentations were performed by a board-certified neuroradiologist using AIA, providing same tools as in clinic. Initially, nnU-Net (M1) was trained on a 227 single institution dataset. A team of clinicians, researchers, and data scientists assessed the model's performance visually and quantitatively using AIA. In particular, false positive and negative segmentations were analyzed, and MR image quality was assessed by a second board-certified neuroradiologist using AIA. Algorithm was retrained and tested based on the feedback. This methodology was iterated. Modified nnU-Net (M2) and STU-Net with brain masking (M3) trained on BraTS-METS2023 dataset were investigated. Precision and sensitivity were used as metrics for BM detection.

Barriers/Challenges

A team of clinicians, researchers, and data scientists had to assess the MR image quality, ground truth segmentation masks, and AI-predicted segmentation masks manually to determine the strengths and weaknesses of the algorithm, which was then used to inform the iterative improvement of the AI algorithm.

Outcome

A total of 607 cerebral metastases from 156 studies from 40 patients were investigated. In BM detection, precision and sensitivity were 0.859 and 0.633 for M1, 0.921 and 0.825 for M2, and 0.924 and 0.827 for M3, respectively. False positive AI-predicted BMs outside of the brain were eliminated in M3.

Conclusion/Statement of Impact/Lessons Learned

AIA enables the development and iterative improvement of segmentation models. Our network, translatable to clinical PACS, provides precise automated detection and segmentation of brain metastasis.

Figure(s)

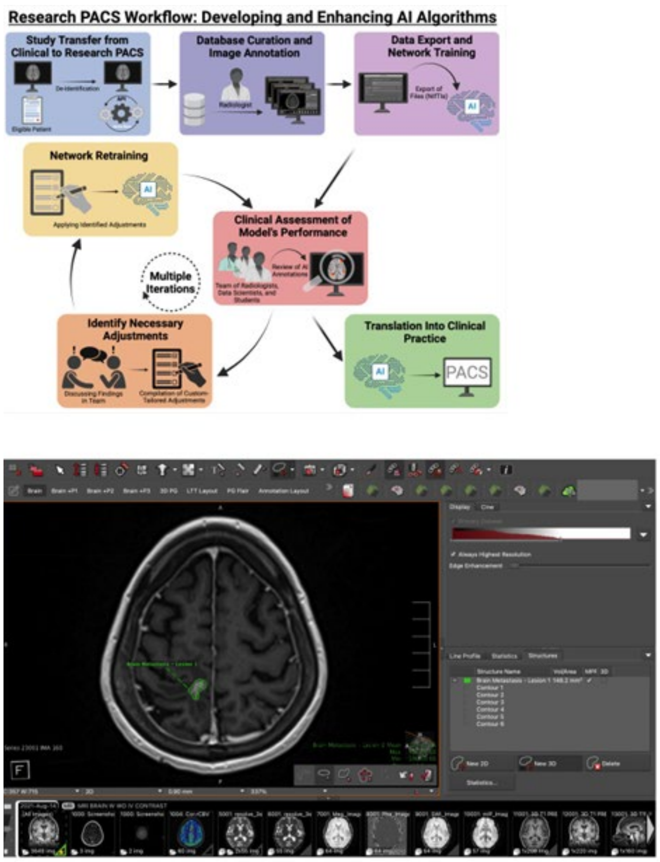

Figure 1. Development and Enhancement of the models

Parameter	All identified lesions	Lesions ≥5mm	Lesions <5mm
True positive lesions	384	331	53
False negative lesions	223	70	153
False positive lesions	63	40	23
Precision	0.859	0.892	0.702
Sensitivity	0.633	0.825	0.257
F1-Score	0.729	0.857	0.376

A. Model 1

Parameter	All identified lesions	Lesions ≥5mm	Lesions <5mm
True positive lesions	501	366	135
False negative lesions	106	35	71
False positive lesions	43	15	28
Precision	0.921	0.961	0.828
Sensitivity	0.825	0.913	0.655
F1-Score	0.871	0.936	0.732

B. Model 2

Parameter	All identified lesions	Lesions ≥5mm	Lesions <5mm
True positive lesions	502	366	136
False negative lesions	105	35	70
False positive lesions	41	12	29
Precision	0.924	0.968	0.824
Sensitivity	0.827	0.913	0.660
F1-Score	0.873	0.939	0.733

C. Model 3

Table 1.

Keywords

Applications; Artificial Intelligence/Machine Learning; Clinical Workflow & Productivity; Imaging Research