ORAL PRESENTATIONS

Improving the estimation of subtle blood-brain barrier permeability changes in aging using a deep learning approach

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Background

Increasing evidence suggests detecting the subtle changes in blood-brain barrier (BBB) permeability in normal aging and in Alzheimer's disease by using dynamic contrast-enhanced MRI (DCE-MRI) (Figure 1).[1,2] However, measuring these subtle changes poses a great challenge for accurate measurement, resulting in inconsistent results among previous studies.[1,2] Two major challenges are long scan times, as suggested by other studies, and the selection of the arterial input function (AIF). In this study, we aim to estimate the capillary level input function (CIF) using a deep learning network to overcome these two challenges.

Methods

Healthy volunteers (n=12, age 21-78) were recruited for DCE-MRI scan for 28 min. Golden-angle radial sampling parallel (GRASP) sequence was used to obtain the dynamic images at ~5s/frame. Individual AIF was sampled from the superior sagittal sinus of the brain. FSL[3] was used to segment the gray and white matter. Each voxel was fitted using the graphical Patlak model[4] to assess the vascular permeability-surface area product (PS) for both 28-min data and 10-min truncated data. We used a 3x3 kernel sliding through the images, and feed each voxel's dynamic as the input to our vision-transformer.[5] Training data were generated using individual AIFs with a mathematical model and used to simulate dynamic patches using the extended Patlak model.[4]

Results

The conventional approach with AIF results in the majority of voxels exhibiting negative PS, regardless of scan time. This is not physiologically valid, as this indicates the contrast agent extravasates into the vessel. However, the proposed approach with the network-predicted CIF results in most voxels in positive PS, even with a scan-time of 10 min. The estimated PS levels are in good accordance with the previous studies.[1] Due to the limited sample size, we could not find the difference in BBB permeability between young and old groups.

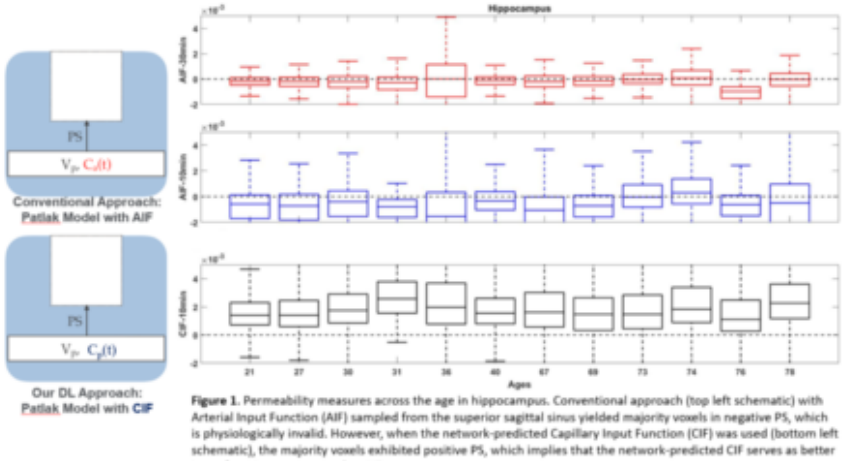

Figure 1. Permeability measures across the age in hippocampus. Conventional approach (top left schematic) with Arterial Input Function (AIF) sampled from the superior sagittal sinus yielded majority voxels in negative PS, which is physiologically invalid. However, when the network-predicted Capillary Input Function (CIF) was used (bottom left schematic), the majority voxels exhibited positive PS, which implies that the network-predicted CIF serves as better input function as compared to AIF.

Figure 1.

Conclusions

Our approach showed promising quantification of subtle permeability. The results in this study suggest that our proposed CIF-based approach provides an appropriate input function for DCE analysis, allowing assessment of subtle permeability changes in the BBB even with a reduced scan time of 10 min. Future studies will include larger cohorts to investigate the BBB permeability changes in normal aging.

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