Statistical Phase Noise Elimination for Amyloid Plaque Detection

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Purpose:

There are several imaging methods to diagnose Alzheimer's disease (AD). Recently, several studies showed that MRI could detect amyloid plaque (AP) on T2 or T2*W-image and MR-phase image. Those excellent studies, however, also commonly have a problem of long scan duration and therefore it looks still difficult to apply them to clinical use of AP detection and diagnosis of AD. Preceding studies revealed AP contained iron materials and reasonably changed susceptibility of AP. Therefore, phase imaging technique is to be first candidate to reduce scan duration for AD examination because of its high sensitivity to susceptibility changing. However, phase information with short scan duration contains much phase noise, which is difficult to be distinguished from signal of AP. In this study, we suggested statistical method to effectively distinguish the signal of AP from phase noise on MR-phase image to reduce scan duration for clinical application of diagnosis of AD. The final goal of this study is to image AP staining of AD patients on clinical MRI with clinically applicable scan duration.

Materials and Methods:

APP23 mouse (fixed 17 m/o) brain scans were done on 7T MRI (BioSpec 70/20 USR, Bruker Biospin, Germany) with 3D-FLASH: TE/TR = 12.8/50 ms, FA = 20 deg., spatial resolution = 0.08^3 mm^3, NEX = 2-24 and scan duration = 10 min-3 hrs (mouse brain surface coil). For human study (average 67 y/o), we used 3T MRI (Achieva 3.0T, Philips Healthcare, the Netherlands) with 2D-FFE: TE/TR = 34.5/893 ms, FA = 50 deg., scan plane = axial, in-plane resolution = 0.45^2 mm^2, slice thickness = 2 mm and scan duration = 3 min 45 sec. All images were derived as Dicom files from MRI system. Phase wrap was removed by homodyne filter and filtered phase histograms of cortex were manually accumulated by set ROI on cortex. Accumulated phase histograms were fitted with two different Gaussian curves and obtained 6 parameters of Gaussians; peak, SD and center of mass (statistical analysis). One of Gaussians represented as phase noise distribution and rest would be AP distribution. We selected filtered phase band below the lower intersection of two Gaussians to enhance AP signal, because AP contained iron staining and theoretically showed negative phase value in left handed system. Selected phase band was enhanced by Phase Difference Enhanced Imaging (PADRE) [1], and PADRE image of APP23 mouse brain were compared with anti-amyloid beta immunostaining and iron staining images (not appeared in this abstract). Human cases with short scan duration were also reconstructed along above way.

Results:

The average lower intersection of two Gaussians for APP23 mouse brain was about 2% of -pi [rad] (Fig. 1). We selected phase band below 2% of -pi to enhance AP on PADRE image. Signals of PADRE images of APP23 mouse brain were coincident with AP on immunostainig image (Fig. 2 arrows). In human cases, we set 3% of –pi by taking SNR into consideration. AD images of human cases always showed "dark rim sign" along the cortex especially for visual and temporal cortex where Arnold et al. already reported as one of the most AP stayning location [2] (Fig. 3 left). However, PADRE image of healthy control did not show any such suspicious lim or spot on both of visual and temporal cortex, which meant this statistical method might remove iron deposition by aging as phase noise (Fig. 3 right).

Conclusions:

Our statistical method to eliminate phase noise could correctly select and enhance AP phase on PADRE image. For human cases, PADRE image showed dark rim sign expected as AP deposition but did not show background phase noise containing iron deposition due to aging. Therefore, this statistical noise elimination method may be applicable for clinical image diagnosis for AD with reasonable scan duration less than 4 min.

References:

[1] T. Yoneda et al., ISMRM, 2764 (2009), Shingo Kakeda et al., Eur. Radiol., **21**, 2202-2210 (2011).
[2] S. E. Arnold et al., Cerebral Cortex, **1**, 103-116 (1991).

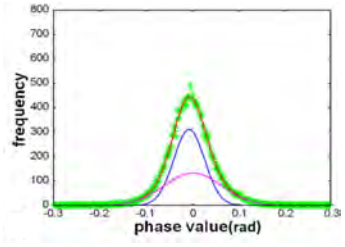

Fig. 1: Phase data was fitted with two Gaussians and lower intersection of them (arrow) was used as threshold to eliminate phase noise.

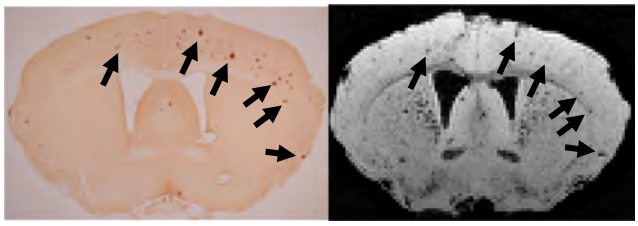

Fig. 2: Many enhanced dots in PADRE image with statistical phase selection (right) are coincidence with AP dots on immunostaining image (left) shown by arrows.

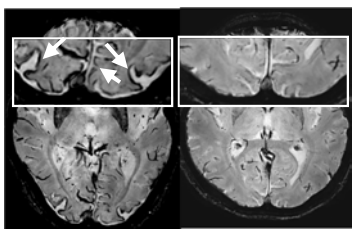

Fig. 3: PADRE images of human AD patient (left) and healthy control (right). Dark rims in the visual cortex, which are considered as sign of AP staining, are seen only on the patient image.