A SIMPLE AND PRACTICAL METHOD TO OPTIMIZE REGULARIZATION PARAMETERS IN COMPRESSED SENSING RECONSTRUCTION OF TIME-OF-FLIGHT (TOF) MR ANGIOGRAPHY

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PURPOSE: Since its early introduction, image reconstruction from randomly under-sampled data with Compressed Sensing (CS) technique [1] has been widely investigated. With MRI, cerebral arteries can be visualized by conventional time-of-flight (TOF) technique and has been widely used in clinical routine MR imaging. In contrast to previous reports for contrast-enhanced MRA, reports on applying CS to TOF-MRA is still limited, probably because of difficulty due to a relatively lower SNR, and is challenging. Compressed Sensing reconstruction requires tuning of the regularization parameters. One of the approaches is to measure NMSE. Another approach named the L-surface method tries to balance data consistency and L1 penalty [2]. When optimizing regularization parameter(s) for the TOF-MRA data, simple quantitative error measures such as the NMSE may not be appropriate because these do not necessarily correlate with visualization of peripheral arteries. Structural similarity (SSIM) accounts for spatial correlation of coefficients at each voxel and can simulate human perception in structure [3]. Nevertheless, this method may not be sufficient for evaluation of fine structures such as peripheral arteries. In this work, we propose a simple and practical method to select a good regularization parameter applicable to TOF-MRA image reconstruction. The proposed method was compared with the conventional method, and the results were evaluated by a clinical neuroradiologist.

METHODS: Study protocols were approved by the local ethics committee. 3D TOF-MRA was performed for a healthy volunteer at 3T-MR system (Vantage, TOSHIBA MEDICAL SYSTEMS CORPORATION, Otawara, Japan) using a 32-channel head coil (TR/TE = 20/3.4ms, FA = 15°, matrix = 256x256x110, voxel size = 0.8 x 0.8 x 1.0 mm^3). Data were retrospectively under-sampled with a rate of 25% (4x acceleration) by using a variable-density Poisson disk pattern. In this study, we used sum of squares (SoS) image as a reference standard. CS reconstruction was performed by an in-house MATLAB script on an off-line workstation (Core i7-4930).

After reducing the data size by a coil-compression technique [4], CS reconstruction was performed by the FCSA algorithm [5]: min (1/2)|y-Ax|_2^2 + alpha*|psi(x)|_1 + beta*|TV(x)|_1, where psi and TV represent Wavelet transform and total variation, respectively. Alpha and beta are regularization parameters and varied with a range of {0.01, 0.1, 0.2, …, 0.9, 0.93, 0.99; relative amount of coefficients to be thresholded}, and {1e-3, 1e-4, …, 1e-10;a.u., absolute value}, respectively. The number of iterations was fixed to 30 for each parameter. A mask corresponding to the brain region was drawn (fig 2, bottom-left) by an experienced radiologist, and was used for the data analysis. At each iteration step, reconstructed image was evaluated with the NMSE of the whole pixel data, averaged SSIM of each of the stacked 2D images, NMSE / SSIM of the MIP image, and NMSE / SSIM of the masked MIP image. The best image was selected with each quantitative measure, and the resulting 6 images selected with those 6 measures were evaluated by a radiologist with an experience of 17 years, and the best image was subjectively selected.

Figure 1.

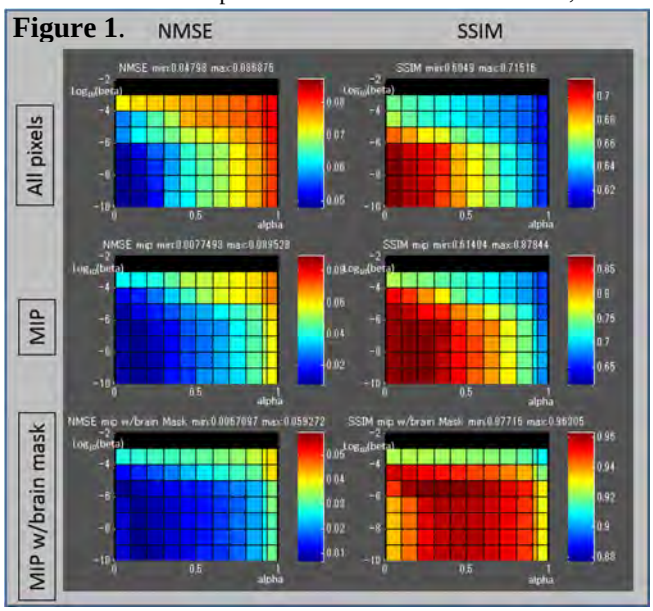
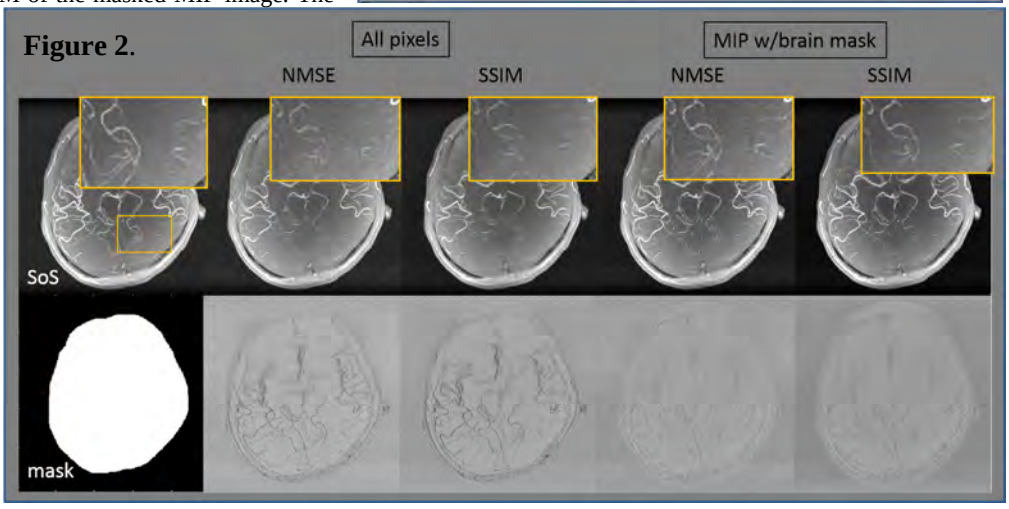


Figure 2.



RESULTS: Image reconstruction took about 14 minutes for 30 iterations. The values of the quantitative measures versus the values of alpha and beta were summarized in Figure 1. Among 6 evaluation criteria, images with the least NMSE, best SSIM, least NMSE by a masked MIP, and best SSIM by a masked MIP were shown in Figure 2. The image selected by the highest SSIM value by using a masked MIP image was considered best by a clinical radiologist's evaluation. Regularization parameters for this image were: alpha = 0.3, beta = 1e-5.

DISCUSSION: When optimizing regularization parameters for TOF-MRA, using a mask for the region of (Radiologists') interest seems reasonable. This study has shown feasibility of the concept.

CONCLUSION: Brain mask for MIP image of TOF-MRA is useful for optimizing regularization parameters for CS reconstruction.

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