COMPARISON OF 2D VERSUS 3D SPARSE PRIORS IN COMPRESSED SENSING RECONSTRUCTION OF TIME-OF-FLIGHT (TOF) MR ANGIOGRAPHY

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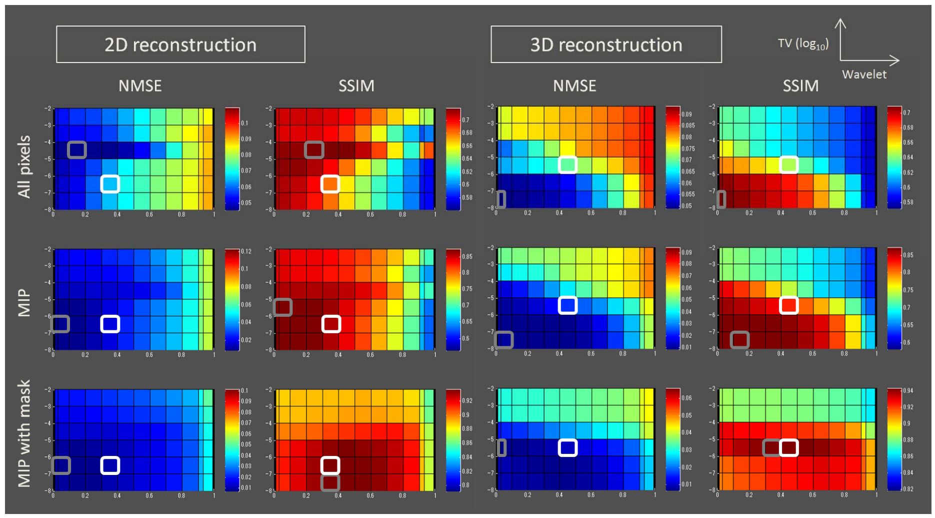
PURPOSE: Since its early introduction of Compressed Sensing to the reconstruction of MR images [1], its application to non-contrast enhanced Time-of-Flight (TOF) MRA of the brain has been challenging. One of the reasons is its relatively lower SNR compared with contrast-enhanced MR angiography. Because of its easy implementation for parallel processing and smaller memory requirement, under-sampled 3D k-space data is usually Fourier transformed in the readout direction and converted to a 2D-CS reconstruction problem [2]. When considering sparsity, direct 3D reconstruction with 3D wavelet and 3D total variation (TV) should have better performance especially in a lower SNR scenario. There are previous reports that exploit sparsity in 3D for T2-weighted FSE images [3] and MR spectroscopy [4]. We investigated the advantage of 3D sparsifying transformation for the reconstruction of non-contrast enhanced TOF MRA data by comparing it with 2D-based reconstruction.

Figure 1

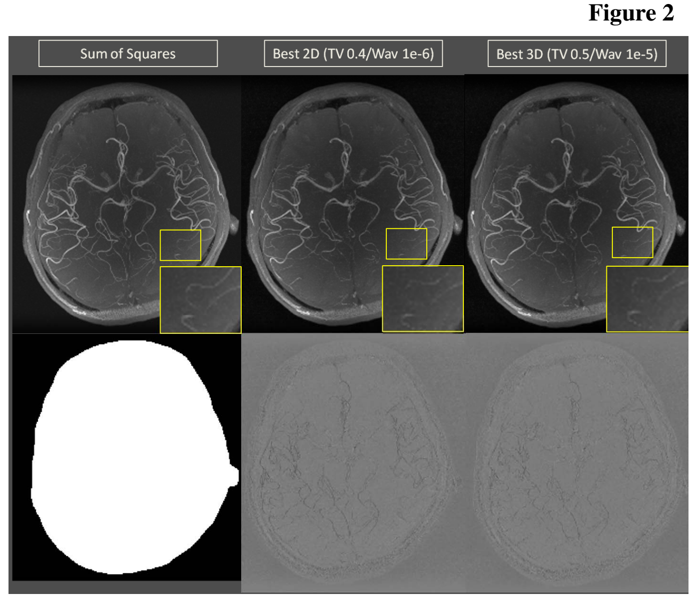


METHODS: Study protocols were approved by the local ethics committee. 3D TOF-MRA was performed for a healthy volunteer at 3.0T (Vantage, TOSHIBA MEDICAL SYSTEMS CORPORATION, Otawara, Japan) using a 32-channel head coil (TR/TE = 20/3.4 ms, FA = 15°, matrix = 256 x 256 x 110, voxel size = 0.8 x 0.8 x 1.0 mm^3). Data were retrospectively under-sampled with a rate of 25% (4x acceleration) by using a variable-density Poisson disk mask. In this study, we used the sum of squares (SoS) image as the reference standard. Image reconstruction was performed by an in-house script developed with Matlab. After reducing the data size by a coil-compression technique [5], CS reconstruction was performed by the FCSA algorithm: 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 [6]. Alpha and beta are regularization parameters and varied with a range of {0.01, 0.03, 0.1, 0.2, …, 0.9, 0.93, 0.99; relative amount of coefficients to be thresholded}, and {1e-2, 1e-3, …, 1e-8; a.u., absolute value}, respectively. The number of iterations was fixed to 30 for each parameter. By use of an outline extraction algorithm, a mask that corresponds to the head region was drawn and used for data analysis (Figure 2). At each iteration step, the reconstructed images were evaluated with error measures, namely the NMSE of the whole pixel data, averaged SSIM of each of the vertical 2D images, NMSE / SSIM of the MIP image, and NMSE / SSIM of the masked MIP image. Best images for each regularization parameter (13 x 7 x 2 (2D or 3D) = 182 in total) were evaluated by two radiologists with clinical experience of 6 years and 14 years respectively, and the best images for 2D and 3D were selected subjectively.

RESULTS:

Image reconstruction with 30 iterations took approximately 14 minutes for both 2D and 3D reconstructions. The best quantitative value among all iterations versus the regularization parameters for wavelet and TV are summarized in Figure 1. The regularization parameters for wavelet/TV for the best images subjectively chosen by two radiologists were 0.40/1.0e-6 for 2D reconstruction and 0.50/1.0e-5 for 3D reconstruction. The best parameter sets chosen quantitatively and subjectively are depicted in Figure 1 as gray and white squares, respectively. For both 2D and 3D, the results of subjective evaluation corresponded very well with those of quantitative evaluation with SSIM values of the masked MIP image. The SoS image, best 2D and 3D-reconstructed images and its respective subtraction images with the SoS image are shown in Figure 2. The image quality of the best 3D-reconstructed image was slightly superior to the best 2D-reconstructed image, in terms of both quantitative and subjective evaluation.

Figure 2



CONCLUSION: CS reconstruction of non-contrast enhanced TOF MRA data performed in 3D yields higher quality images than those performed in 2D.

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