SNR Quantification with Phased-Array Coils and Parallel Imaging for 3D-FSE

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INTRODUCTION: Recently a novel 3D fast-spin-echo sequence (3D-FSE-Cube) has been developed for structural imaging of the head, abdomen and extremities [1,2]. The application of parallel imaging, phased-array coils and partial Fourier acquisition alters the spatial and statistical distributions of image noise, respectively [3]. This study measured noise via noise-only acquisitions (acquired with no RF excitation) and compared resulting signal-to-noise and contrast-to-noise ratio (SNR and CNR) measurements with the traditional foreground and background volume of interest (VOI) estimation method [3,4]. To measure noise statistics in noise-only acquisitions, noise should be processed through the identical linear reconstruction pipeline as signal data, which may involve data-dependent steps such as parallel imaging, partial Fourier homodyne and multichannel reconstructions [5].

METHODS: The right knees of 7 healthy volunteers (mean age 27 yrs, range 21–32 yrs) were imaged using a GE Signa 3T MRI and an 8-channel transmit-receive knee coil. Each subject was imaged 20–22 times with sagittal proton-density 3D-FSE-Cube with different TR, BW, ETL, NEX and acceleration factor combinations for a total of 146 scans. Imaging parameter ranges used were TR 1000–5750ms, BW ±31.25–125kHz, ETL 45–120, NEX 0.5–2 and autocalibrated parallel imaging acceleration factors of 1–3.75. All scans utilized fat saturation and the following fixed acquisition parameters: 35ms TE_{eff}, 256x256 matrix, 16cm FOV, 180 slices at 0.6mm slice thickness. Noise-only data was acquired with RF turned off for each unique combination of parameters. Both signal and noise-only data were reconstructed offline to apply parallel imaging calibration weights, homodyne partial Fourier phase correction and multichannel image combination to the noise-only data (see Figure 1). For all 146 scans, SNRs were calculated for muscle, cartilage and synovial fluid, and CNRs were calculated for fluid and cartilage. VOIs were placed in the reconstructed signal images to measure mean signal intensities and duplicated in the noise-only reconstructions to measure noise. SNR and CNR were also calculated using the traditional foreground and background method. Tissue VOIs were maintained from the prior SNR measurement while noise was quantified as the standard deviation of background noise in a signal-free region anterolateral to the knee. Traditional SNR and CNR measurements using the foreground and background approach were compared to SNR and CNR calculated from signal and noise-only acquisitions using paired t-tests.

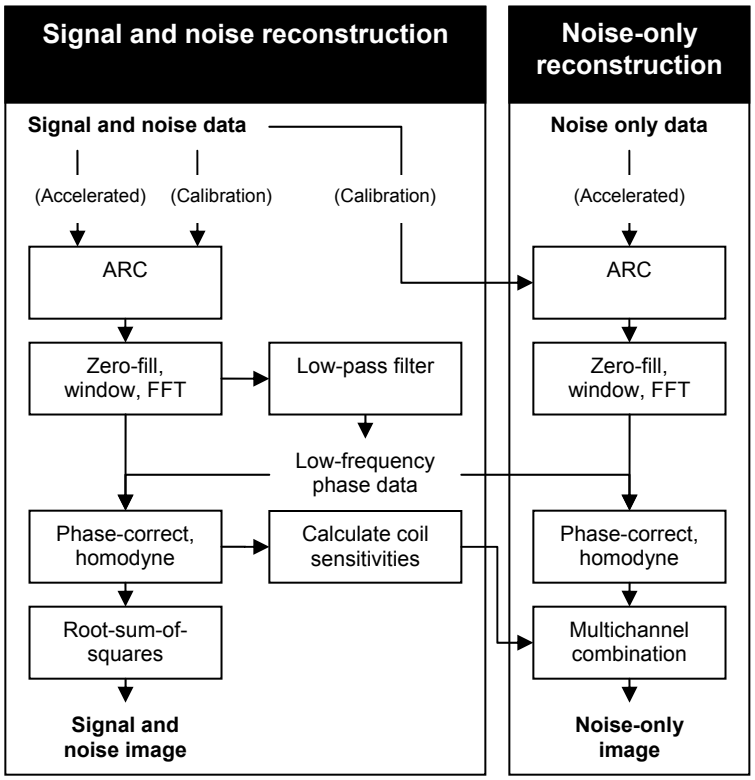

Figure 1. Image reconstruction pipelines for signal data and noise-only data. Noise is reconstructed through a pipeline identical to signal data while incorporating signal data in parallel imaging, homodyne and multichannel image combination.

RESULTS: SNRs calculated for muscle, cartilage and synovial fluid were significantly overestimated using the traditional foreground and background method ($p < 0.0001$). Average errors relative to measurements from the noise-only acquisitions were 299%, 376%, 224% and 250% for fluid SNR, muscle SNR, cartilage SNR and fluid-cartilage CNR, respectively (see Figure 2). Because signal intensity was unchanged for all SNR and CNR measurements, overestimation of SNR and CNR is attributable to underestimation of image noise. This observation follows the theoretical prediction of reduced noise in regions without signal due to spatially-varying geometry factors in parallel imaging [6].

CONCLUSION: Acquisition and reconstruction of noise-only data parallel to signal data provides measurements of image SNR and CNR significantly different from traditional foreground and background estimation methods in 3D-FSE-Cube acquisitions. While the reconstruction pipeline described was tailored for 3D-FSE-Cube acquisitions, this noise measurement technique is generalizable to any sequences utilizing parallel imaging, partial Fourier acquisition and multichannel image combination.

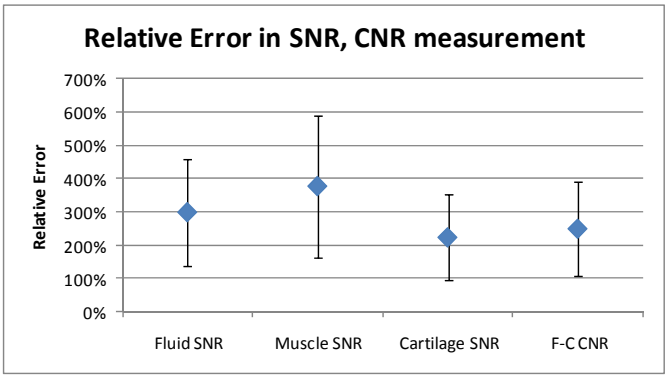

Figure 2. SNR and CNR calculated using the foreground and background method are significantly greater than measurements from noise-only reconstructions. Error bars represent standard deviations.

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