Signal-to-Noise Ratio of IDEAL-separated water and fat images from accelerated acquisitions

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Introduction: The method of Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation (IDEAL) (1, 2) produces separate images of water and fat in the body from the acquisition of echoes at three different echo times. This leads to three-fold increase of examination times that may be compensated for by the use of parallel imaging. Evaluation of the precise effects on Signal-to-Noise Ratio (SNR) of an accelerated IDEAL acquisition is problematic because estimation of SNR is hindered in parallel imaging by spatial variation in the image noise (3) which can result in unreliable estimation of SNR with the conventional Region-of-Interest method (4). Simple analytical estimation of SNR (1, 5) is dependant on equal noise variance in each of the IDEAL echoes which is not always true for parallel imaging acquisitions, particularly for some self calibrated parallel strategies for IDEAL (6) where different levels of acceleration are used for the images acquired at different echo times. In this work we demonstrate the combination with IDEAL of a method for producing images whose signal intensity is in units of SNR (7) which does not require the image noise to be analytically known, allowing iterative conjugate gradient reconstruction techniques to be used (8). The resulting "SNR-scaled" fat-only and water-only images with signal intensity in units of SNR may prove useful in guiding choices of how best to use parallel imaging strategies with IDEAL.

Methods: A *pseudo* multiple replica SNR measurement is employed. Multiple image replicas are reconstructed from the same *k*-space with correctly scaled and correlated Gaussian distributed random noise added for each replica. The added noise is correlated by the square root (Cholesky decomposition) of the noise covariance matrix which is measured during a noise pre-scan where the receiver is opened with no normal signal present and with the phased-array coil loaded as for imaging (7). SNR may then be mapped on a pixel-by-pixel basis from the mean and standard deviation of image pixel values in the stack of complex image replicas and the stack of water and fat IDEAL image replicas. Three schemes of 1-D parallel imaging acceleration with the same total acceleration factor of 2 were investigated by decimation of the same fully-sampled *k*-space from a 3D coronal abdominal IDEAL image acquisition, with an image matrix of 256 frequency encodes (read-out SI) × 104 phase encodes × 16 slice encodes in a 22 second breath-hold. An equivalent scan was acquired with no applied RF from which the noise covariance matrix was measured.

Results: Figure 1 shows IDEAL-decomposed magnitude and SNR-scaled water and fat images for three *k*-space sampling schemes with net twofold acceleration: i) all three echoes have an under-sampled periphery with outer reduction factor (ORF) of 3 plus the first echo only has a fully sampled center of 68 phase encode lines; ii) all echoes have an ORF of 4 and a fully sampled center of 34 lines, iii) all echoes have an ORF of 5 and a fully sampled center of 40 lines. The SNR-scaled images show differences in the SNR of the water and fat images acquired with sampling schemes (i) and (ii) that are not clearly evident in the magnitude water and fat images alone. Furthermore the SNR-scaling method shows quantitatively the SNR differences resulting from the two similar *k*-space acquisition patterns (ii) and (iii). The mean SNR values for ORFs 3, 4, and 5, respectively are: in the ROI in the liver in the water image, 70±1, 59±1, and 40±1; and in the fat image, 140±3, 107±3, and 82±2.

Discussion: The SNR measurement proposed will also allow investigation into different IDEAL decomposition algorithms, for example, incorporating weighted least-squares routines into the IDEAL decomposition to account for T_2^* signal-decay (9). Furthermore, because it is based on a single acquisition and is therefore insensitive to instrumental drift, the *pseudo* multiple replica method used here may out-perform acquisition of multiple *actual* images. Such an approach is necessary for *in vivo* imaging where patient motion between replicas is prohibitive for pixel-by-pixel analysis. SNR-scaled water and fat images may also be useful complements to the magnitude images for inspecting anatomical features, and for providing estimates of measurement error when the IDEAL method is used for fat quantification.

Conclusion: The *pseudo* multiple replica SNR measurement method can be successfully used with the IDEAL decomposition to produce water and fat images in units of SNR from a single acquisition of *k*-space plus a rapid noise pre-scan, allowing application to *in vivo* imaging. The method is able to map SNR when noise variance is spatially variant due to parallel imaging, is not equal in images acquired at different echo times, or when image noise variance is not calculable analytically, allowing investigation into the effects on image SNR of combining IDEAL acquisition with parallel imaging techniques.

References: 1. Reeder et al. MRM 2004 51:35-45. 2. Reeder et al. MRM 2005 54: 636-44. 3. Pruessmann et al. MRM 1999 42:952-62, 4. Reeder et al. MRM 2005 54:748-54. 5. Pineda et al. MRM 2005 54:625-35. 6. McKenzie, Proc. ISMRM 2004, 917. 7. Kellman et al. MRM 2005 54:1439-47. 8. Pruessmann et al. MRM 2001 46:638-51. 9. Yu, Proc. ISMRM 2006, 624.

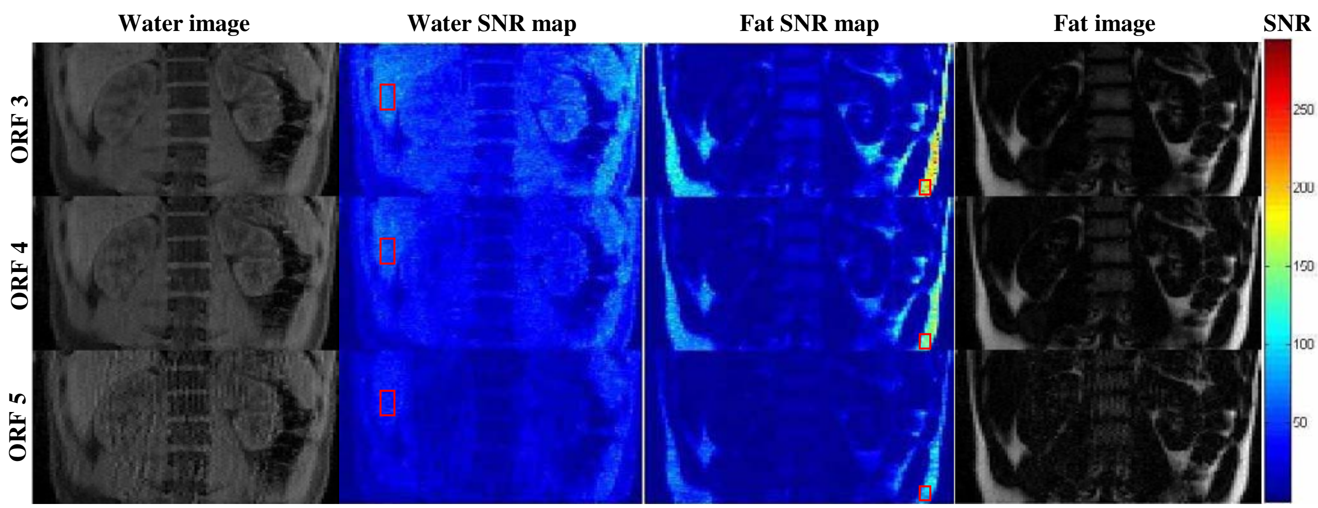

Figure 1: IDEAL decomposed water and fat magnitude images (far left and far right respectively) plotted with same grayscale. Corresponding SNR-unit images of water and fat (middle left and right) plotted with same color-scale. Different acceleration schemes have been used for each row of images for the same total acceleration factor of 2 (see text): i) ORF 3 (top row); ii) ORF 4 (middle); iii) ORF 5 (bottom row). (Mean SNR ROIs shown as red boxes.)