Optimal Apportionment of Acceleration in 2D SENSE

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Introduction: 2D Sensitivity Encoding (SENSE) [1] has been used in 3D contrast-enhanced MR angiography (CE-MRA) with an acceleration factor R as high as R=8 in multiple vascular regions [2,3]. 2D SENSE acceleration can be expressed as $R = R_Y \times R_Z$ where R_Y and R_Z are the individual accelerations along the two phase encode directions, Y and Z. With SENSE both R_Y and R_Z can be non-integer. In CE-MRA many fields of view are markedly different along the two phase encode directions (typically L/R and A/P), possibly making acceleration preferable along one direction vs. the other. Another variable can be the number and sizes of the receive coil elements. Finally, intentionally forcing regions of known zero magnetization to have zero signal in the SENSE reconstruction, a process called "masking," can provide improved SENSE performance. As a consequence of all of these factors, it is not clear for a given acceleration R which combination (R_Y, R_Z) should be used. The purpose of this work is to show how the apportionment of R into its (R_Y, R_Z) components can be optimized. Here the (R_Y, R_Z) pair is selected which best balances noise amplification (g-factor) and acquisition time for a given patient-specific anatomy. This process is demonstrated *in vivo* to yield 20% higher acceleration than a standard (R_Y, R_Z) and with comparable image quality.

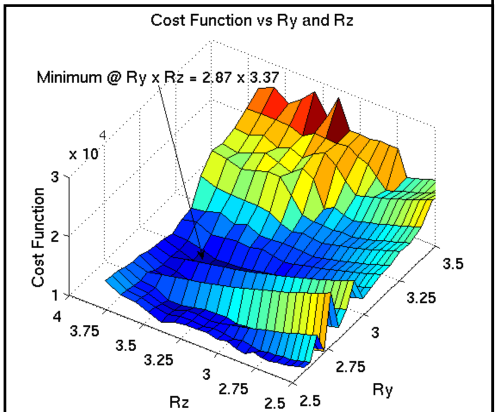

Fig 1: Cost function value vs. R_Y and R_z showing global minimum at 2.87 and 3.37 respectively.

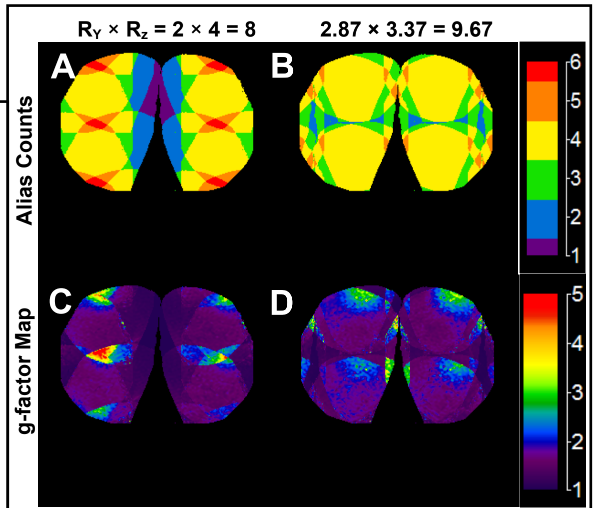

Fig 2: Single phase encoding plane alias count (A,B) and g-factor (C,D) maps of noted $R_Y \times R_Z$ through the midfeet.

Methods: The calibration scan used for measuring coil sensitivities provides the information for choosing the optimum (R_Y, R_Z) pair. A multi-step procedure is used. First, the air outside the tissue in the field of view (FOV) is masked out so that the reconstructred pixels in those regions are set to zero. Next, a volumetric map of the g-factor is calculated for some initial (R_Y, R_Z) pair. The g-factor is then projected along the frequency encode (X) direction, and the maximum value across this 2D projection image is then noted. This maximum projected value multiplied by the acquisition time serves as the cost function. This process is repeated for all candidate (R_Y, R_Z) pairs. Using a standard mathematical optimization routine allows finding the minimum of this cost function, and the resultant R_Y and R_Z accelerations can be readily applied to the CE-MRA acquisition. Sampling of R_Y-R_Z space at intervals of about 0.1 seems to provide adequate precision.

A healthy volunteer was imaged on a 3T GE Discovery MR750 MRI system using a custom 8-ch coil array and a coronal acquisition using a 3D fast spoiled gradient echo sequence with TR of 6.4ms, 400 × 264 × 256 (X × Y × Z) matrix and 0.75 × 0.75 × 1 mm^3 voxel size using the N4 CAPR technique [4]. An initial study used a reference acceleration of $R_Y \times R_Z = 2 \times 4$, resulting in an update time of 7.4 seconds and a temporal footprint of 27 seconds. On a second day the volunteer was again imaged, and the optimized accelerations of $R_Y \times R_Z = 2.87 \times 3.37$, R = 9.67 were applied, resulting in an update time of 6.2 seconds and a temporal footprint of 24 seconds.

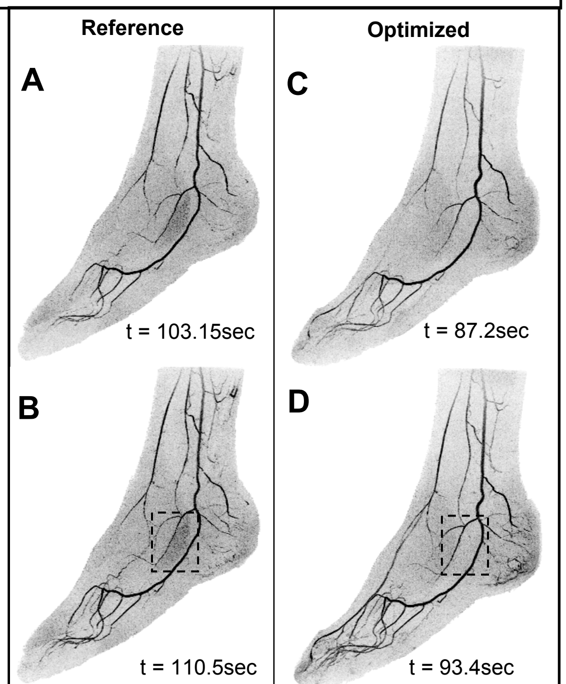

Fig. 3: Sagittal right foot MIPs of roughly equivalent arterial phases of the $R_Y \times R_Z = 2 \times 4$ (A, B) and 2.87 x 3.37 (C, D) acquisitions from the same volunteer. Post injection time is shown.

Results: Fig. 1 shows the cost function for this experimental example. Fig. 2 shows aliasing patterns and g-factors in an axial partition through the midfeet using the reference and optimized R_Y and R_Z values as indicated. Note that with optimized apportionment R has been increased by over 20% while the extent of high alias regions has been reduced (B vs. A) with comparable if not superior g-factor (D vs. C). In Fig. 3 results of the 3D CE-MRA exam using the reference R=8 (A,B) exhibit a region of increased noise in the region with high aliasing (black boxes) which is suppressed in the results with optimized R=9.67 (C,D) due to the improved aliasing pattern with optimum acceleration apportionment. In other aspects the overall image quality of these two exams is comparable.

Conclusion: We have presented the new technique of optimized apportionment of acceleration in 2D SENSE. The feasibility study suggests that it provides an approximate 20% increase in acceleration with negligible penalty in SNR. Although not done for this work, the optimization can potentially be performed within 10 sec of completion of acquisition of the coil calibration data, allowing practical implementation and use of optimum (R_Y, R_Z) based on patient-specific anatomical properties.

References: [1] Weiger M, MAGMA 14:10(2002); [2] Haider CR, Radiol 253:831(2009); [3] Mostardi PM, Radiol 261:587 (2011) [4] Haider CR, MRM 60:749(2008)