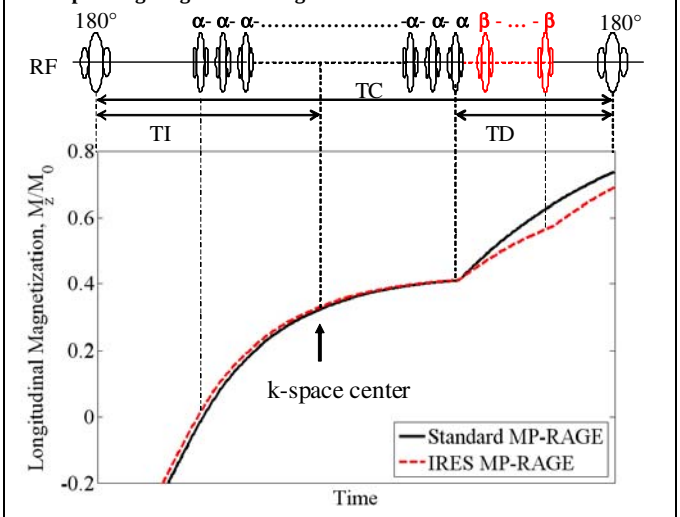
IRES: Self-Calibrated Parallel Imaging with No Loss of Net Acceleration

E. T. Tan[1], R. C. Grimm[1], and S. J. Riederer[1]
[1]Radiology, Mayo Clinic, Rochester, MN, United States

Introduction – Self-calibrated parallel imaging provides accelerated acquisition in MRI with little or no residual aliasing artifacts [1]. Compared to the sparsely sampled k-space periphery, the central k-space region is fully sampled for calibration data. However, this reduces the net acceleration, and this reduction worsens with higher acceleration factors. In an inversion-prepared sequence such as magnetization prepared rapid gradient echo (MP-RAGE) [2], a long delay interval allowing recovery of magnetization follows the readout of data for each cycle. The idea of inversion recovery with embedded self-calibration (IRES) is to acquire the calibration data only within this delay interval with only minimal perturbation to magnetization recovery. This results in no reduction in acceleration due to self-calibration. Compared to standard self-calibration, IRES may thus provide either (i) further time-savings or (ii) higher image quality at the same scan time.

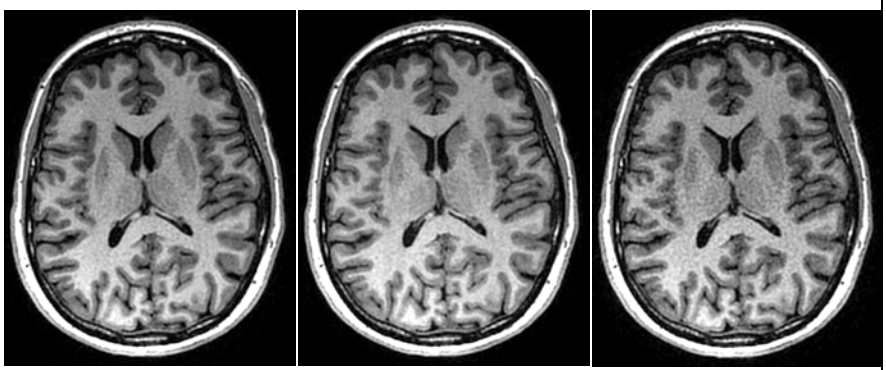
Methods – Fig. 1 illustrates an MP-RAGE cycle of flip angle α and the corresponding longitudinal magnetization. With IRES, a gradient echo train of flip angle β is added within the delay interval TD for calibration. When β is small (≤ 4°), IRES results in minimal perturbation to magnetization shown in red (dash). An IRES acquisition with 2D acceleration of $R = R_{net} = 4$ was compared to a standard self-calibrated (SC) sequence also of $R = 4$ but yielding only $R_{net} = 3$, and to another SC sequence of $R = 6$ with $R_{net} = 4$. These comparisons were made with a tissue-mimicking phantom (15 trials, Cycle Time/TI/TR/TE = 2300/900/6.4/2.8 msec, $\alpha / \beta = 8°/4°$, 170/63 α / β repetitions per cycle, FOV = 20 cm, sampled at 256×168×168, 0.8×1.2×1.2 mm^3), and in vivo with six volunteers (FOV = 26 cm, sampled at 256×240×204, 1 mm^3, 81 β repetitions per cycle). Differences in SNR measurements between IRES and either SC acquisition were recorded. Image reconstructions were performed with GRAPPA [1].

Fig. 1: MP-RAGE pulse sequence with IRES, and plots of the corresponding longitudinal magnetization



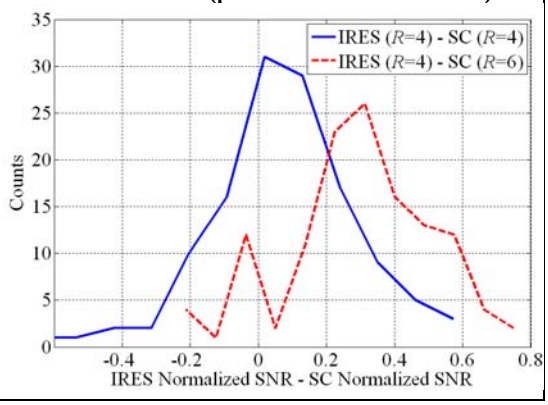
Results – In Fig. 2, in-vivo images show that for the same nominal acceleration ($R = 4$) both image quality and contrast are comparable between SC (a) and IRES (b). Also, IRES (b) is superior to SC (c) for the same scan time. In both the phantom and in-vivo, the SNR and contrast-to-noise ratio (CNR) between IRES and SC at $R = 4$ were statistically indistinguishable ($p > 0.05$), while SNR and CNR in IRES $R = 4$ were superior to SC $R = 6$ ($p < 0.05$). Fig. 3 shows histograms of SNR differences from one comparison.

Fig. 2: In-vivo MP-RAGE images of SC (a, c) and IRES acceleration (b)



(a) SC R=4, Time=2.9 min (b) IRES R=4, Time=2.2 min (c) SC R=6, Time=2.2 min

Fig. 3: Histograms of in-vivo gray matter SNR differences between IRES and SC (positive means IRES is better)



Discussion and Conclusion – IRES was demonstrated in brain imaging with MP-RAGE at $R = 4$ with no loss of R_{net}. In general, SC should have higher SNR than IRES at the same R because IRES does not incorporate calibration data for added SNR. This effect did not prove to be significant in this work. Further, acquisition of calibration data can be maximized in IRES with no loss of R_{net}. IRES acceleration can also be applied to other applications of inversion recovery imaging, such as non-contrast-enhanced MRA [3].

References – [1] Griswold M, MRM 2002; [2] Mugler JP, MRM 1992; [3] Nishimura DG, MRM 1988.