MSVAT-SPACE for fast metal implants imaging

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Introduction SEMAC and MAVRIC are two recently developed techniques, which are able to significantly reduce the geometric distortion caused by metallic implants in MR examinations. However, both two methods are suffering from long scan time due to their intrinsic feature of 3D acquisition. In this abstract, the limitations of these two methods in terms of sampling efficiency are analyzed and an improved implementation, which is extended from the idea of a SEMAC-MAVRIC hybrid method, is presented to show the improved imaging speed.

Analysis and Methods SEMAC originated from the 2D VAT (View Angle Tilting) -Spin Echo sequence, and its implementation reserves the features of 2D sequence: a) rigid reordering with limited echo train length; b) constant refocusing flip angles, which will suffer form SAR problem on high field system. Furthermore, SEMAC is prone to residual distortions in locations with strong B0 inhomogeneity. In a conventional 2D Spin Echo sequence, the slice coverage can be flexibly extended by inserting a gap between two adjacent slices. However, SEMAC can not inherit this feature because significant signal intensity discontinuity may occur in regions with strong through-plane distortions if there is a gap between the adjacent excitations (see Fig1). Unlike SEMAC, MAVRIC employs overlap between adjacent off-resonant excitations, which helps to reduce the signal discontinuity in the distorted region. MAVRIC is purely based on 3D acquisition and owns many advanced acceleration techniques, such as parallel imaging along both Ky and Kz direction and elliptical sampling in Kz-Ky plane. However, because of its non-selective excitation, MAVRIC may need additional z-phase encoding steps to avoid the signal aliasing from insufficient coverage. Generally, this kind of single-slab acquisition limits its capability for flexible coverage in slice direction and shows low sampling efficiency compared to multi-slab acquisitions. Based on the above analysis, an optimal implementation (Multi-Slab acquisition with VAT gradient, based on SPACE[4], abbr. MSVAT-SPACE) includes these features: 1) based on a 3D turbo spin echo sequence, with variable refocusing flip angles to reduce blurring in long echo train acquisitions and SAR limitations on high field systems; 2) using selective excitation and refocusing pulses to enable VAT gradients in the slice axis to completely recover the inplane distortion; 3)using multiple slab acquisition with extended z-phase encoding steps and overlap between adjacent slabs to correct through-plane distortion and reduce signal intensity discontinuity; 4) the excitation thickness and the total number of slabs is adjusted according to the desired slice coverage and the degree of the through-plane distortion resulting in a very efficient interleaved sampling for each TR; 5) elliptical sampling, partial Fourier acquisition, and parallel acquisition techniques are implemented to further reduce scan time.

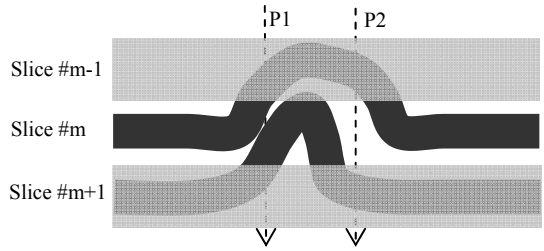

Fig1. Illustration of the signal intensity discontinuity caused by excitation gap between two adjacent slices. At the projection P1 of slice #m, signal pileup occurs because the signal in the slice gap are excited and resolved into slice #m by the z- phase encoding steps. At the projection P2 of slice #m, there is signal void due to the incomplete coverage in the frequency domain.

Results MAVRIC was implemented based on the SPACE sequence. As shown in Fig2, experiments were performed on a 1.5T clinical MR scanner (MAGNETOM Avanto, Siemens, Erlangen) comparing 2D TSE, MAVRIC-SPACE, and MSVAT-SPACE on patients with total knee replacements with the following parameters: 2D TSE: TR = 3330ms, TE = 46ms, image matrix [PE x RO] = [256 x 256], slices = 36 (Slice gap = 0), slice thickness = 2.5mm, total acquisition time = 2min30sec. MAVRIC-SPACE: TR =2000ms, TE = 52ms, image matrix [SL x PE x RO] = [36 x 256 x 256] with resolution = [2.5mm x 0.78mm x 0.78mm], 28 excitations (including 27 off-resonant excitations) in 3 TRs, total acquisition time 6min30sec. MSVAT-SPACE: TR =2000ms, TE = 47ms, image matrix [SL x PE x RO] = [36 x 256 x 256] with resolution = [2.5mm x 0.78mm x 0.78mm], total 28 slabs with interleaving acquisition in 3 TRs, the slab excitation thickness = 7.2mm, the z-phase encoding is uniformly extended by about 10 times in all slabs, total acquisition time 6min30sec. Both MAVRIC-SPACE and MSVAT-SPACE shared these same configurations: 50% of overlap between adjacent slabs or excitations, 1.7 kHz effective RF bandwidth, elliptical sampling in Kz-Ky plane, parallel acquisition with acceleration factor 2 in PE direction. In both MAVRIC-SPACE and MSVAT-SPACE, the echo train length is up to 60, and 98% of the time in each TR was used for data acquisition.

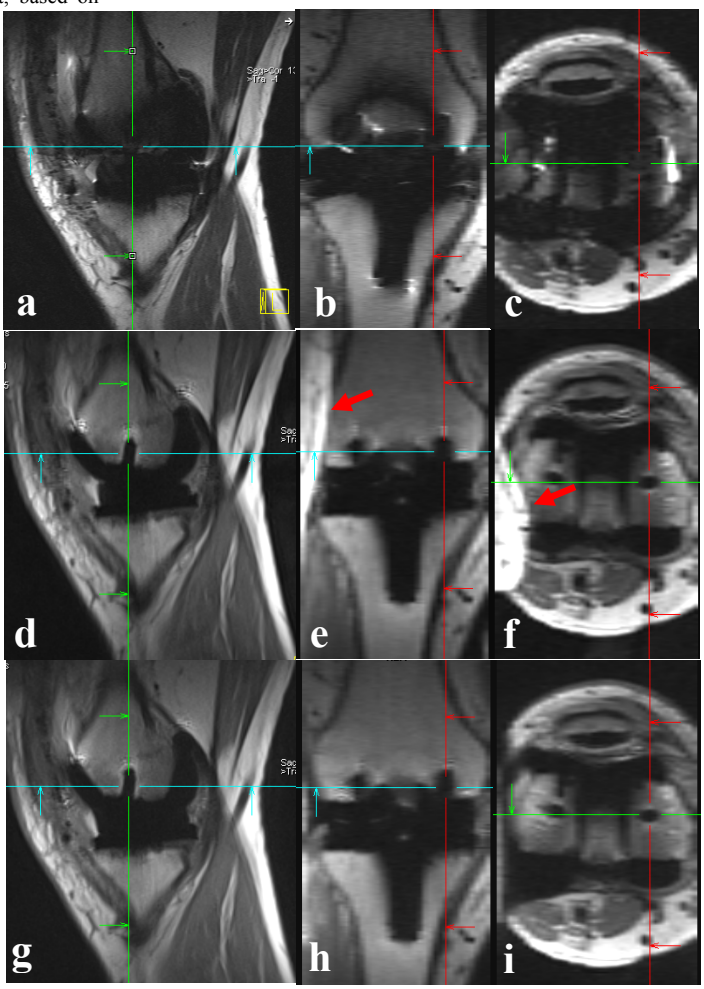

Fig2. 2D TSE (a, b, c), MAVRIC-SPACE (d, e f), MSVAT-SPACE (g, h, i); all images were originally acquired in sagittal orientation, and reformatted onto coronal and transversal plane. Compared to the standard 2D TSE sequence, both MAVRIC-SPACE and MSVAT-SPACE show successful distortion correction, but aliasing artifacts can be observed in MAVRIC-SPACE due to its insufficient coverage in slice direction (red arrows).

Conclusions and Discussion In recent publications, the acquisition time of SEMAC and MAVRIC was usually up to 10 ~20 minutes, with smaller image matrix than presented here. Compared to SEMAC and MAVRIC, MSVAT-SPACE provides much higher sampling efficiency, with reliable distortion correction. Additionally, the extension factor of the z-phase encoding steps or the effective excitation thickness can be adjusted according to the degree of the through-plane distortion in each slab, which may be obtained by a distortion scout sequence, to further reduce the scan time. MSVAT-SPACE is compatible with compressed sensing, which should further contribute to reduce acquisition time.

References [1] Lu W et al., Magn Res Med 2009;62(1):66-76.
[2] Koch KM et al., Magn Res Med 2009;61(2):381-90.
[3] Koch, et al., ISMRM 2010, p139, 2010.
[4] Mugler, ISMRM 2003, p203;