Preliminary Clinical Experience with a Multiecho 2-Point DIXON (mDIXON) Sequence at 3T as an Efficient Alternative for Both the SAR-intensive Acquired In- and Out-of-Phase Chemical Shift Imaging as well as for 3D Fat-suppressed T1-weighted Sequences used for Dynamic Gadolinium-enhanced Imaging

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Introduction As an essential part of abdominal MRI protocols at 3T, most imaging centers acquire chemical shift images based on a specific absorption rate (SAR)–intensive 2D in-phase (IP) and out-of-phase (OP) sequence that often requires multiple breath-holds to cover the anatomy with suboptimal spatial resolution, decreased T1-contrast due to longer tissue T1 values at 3T, and inflow artifacts. Another essential component of the protocol is a 3D fat-suppressed T1-weighted sequence to acquire dynamic multi-phase gadolinium-enhanced imaging to detect and characterize lesions based on vascularity. Recently, a number of other groups have promoted the use of fat/water imaging sequences based on the original DIXON methodology[1], mainly as a new method for fat quantification. Newer 2-point methods[2,3] have relied on the need for the acquisition of at least one IP image, which reduces the degrees of freedom when optimizing imaging acquisition parameters. A recently developed 2-point method, multiecho DIXON (mDIXON)[4], removes these constraints, allowing for the creation of clinically optimized water-only (W) T1-weighted images for dynamic contrast enhanced imaging, as well as more efficient IP, OP, and fat-only (F) imaging protocols. The purpose of this study was to assess whether mDIXON can be an efficient alternative to existing SAR-intensive and time consuming acquired 2D IP and OP images and pre- and post-contrast 3D fat-suppressed T1-weighted (eTHRIVE) images with the goal being significantly reduced overall abdominal MRI exam time at 3T.

Materials and Methods Twenty two patients (mean age 53 $\pm$ 10 yrs) were imaged pre-contrast using an axial 2D dual echo fast field echo (FFE) acquisition to acquire OP and IP images with three breath hold periods of 15 sec each, TR 253/TE1 1.08/TE2 2.19 ms, with typical voxel resolution of 1.7 x 1.5 x 8 mm (1.0 mm slice gap) using a 3T MR system (Philips Healthcare) equipped with a 16-channel SENSE-compatible torso coil, followed by an axial 3D 2-point mDIXON sequence with typical imaging parameters of TR 3.9/ TE1 1.4/TE2 2.7 ms and voxel resolution of 1.4 x 1.2 x 5.0 mm (-2.5 mm reconstructed gap) from which IP/OP/F/W images were reconstructed.[4] For the post-contrast comparison, W images were reconstructed from a breath held axial 3D 2-point mDIXON sequence with typical imaging parameters of TR 4.2/TE1 1.5/ TE2 2.8 ms, and voxel resolution of 1.3 x 1.3 x 2.6 mm (-1.3 mm reconstructed gap). The comparable eTHRIVE protocol utilized fat-suppressed axial 3D turbo field echo (TFE) with typical imaging parameters of TR 3.3/TE 1.57 ms, SPAIR fat suppression, and voxel resolution of 1.6 x 1.3 x 3.0 mm (-1.5 mm reconstructed gap). Image quality for all four sequences was rated on a scale from 1 (unacceptable) to 5 (excellent), and analysed using a 2-tailed t-test to determine if there was a statistically significant difference in image quality between the respective image datasets.

Results For the 22 patients in this study, a statistically significant difference was found in image quality for both the pre- and post-contrast datasets, with the mDIXON demonstrating better image quality in both cases (p=0.004 for the OP/IP and p=0.0009 for the W/fat-suppressed comparisons). Figure 1 shows the improved IP and OP tissue margins and reduced inflow artifacts in the reconstructed IP and OP 2-point mDIXON images when compared to the acquired OP/IP images. With the increased frequency difference between water and the primary fat resonance of 435 Hz relative to lower magnetic fields, any acquired gradient echo images that are not exactly at 1.15 ms (OP) or 2.3 ms (IP) consistently showed inferior W/F boundaries relative to reconstructed mDIXON images. With so many MR system parameters under user control, 2-point mDIXON has the distinct advantage of allowing the user to optimize both the spatial resolution and acquisition time, while allowing the acquired TE values to float. Figure 2 shows the reconstructed coronal OP and IP images for the mDIXON patient data shown in Figure 1. Note the large FH coverage possible within one breath hold acquisition. Figure 3 shows a typical comparison of a post-contrast enhanced eTHRIVE image (a) and the equivalent 2-Point mDIXON W image (c). The gadolinium-enhanced 2-point mDIXON W images showed equivalent anatomical and contrast information as eTHRIVE images on patients, but were found to be higher in spatial resolution due to the mDIXON scanning efficiency available relative to eTHRIVE, a benefit from using the two shortest echo times per TR, and the lack of a time- and SAR-intensive fat-suppression pulse. Note the non-uniformity of the fat-suppression anterior in (a) due to local magnetic susceptibility, while the equivalent mDIXON image (c) shows uniform fat suppression. The overall uniformity of the fat suppression in the 2-Point mDIXON images was never inferior to and, in over 70% of the patients in this study, found to be superior to the equivalent eTHRIVE images.

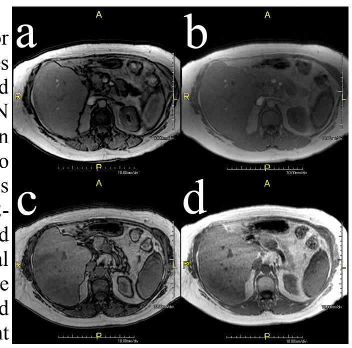

Fig. 1: Acquired 2D dual echo FFE images with OP TE of 1.08 msec (a) and IP TE of 2.19 msec (b) are compared to the 2-point mDIXON calculated OP (c) and IP (d) images.

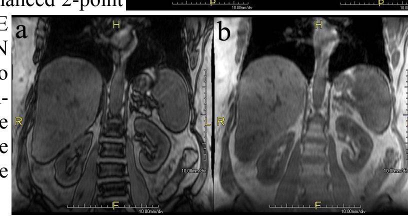

Fig. 2: Reconstructed coronal OP (a) and IP (b) based on the 2-point mDIXON images from the patient data shown in Figure 1c and d showing the large anatomical coverage.

Discussion and Conclusion Our preliminary clinical results with 2-point mDIXON demonstrate that 2-point mDIXON is likely to replace current SAR- and time-intensive 2D acquired IP and OP chemical shift imaging as well as 3D fat-suppressed T1-weighted sequences for dynamic gadolinium-enhanced imaging with improved fat-suppression, spatial resolution, and overall better image quality. The replacement of the two standard sequences (OP/IP and eTHRIVE) with 2-point mDIXON has clinical significance as it allows substantial reduction in the total abdominal MRI examination time. The calculated mDIXON IP and OP images do not suffer from inflow artifacts and allow higher in- as well through-plane resolution with the possibility to perform high-quality reformats (Figures 2 and 3). Higher in-plane resolution will allow more reliable detection of fatty infiltration in smaller liver and adrenal lesions. Similarly, the 2-point mDIXON post-contrast W images demonstrate more uniform fat suppression than eTHRIVE, while providing higher spatial resolution with equal or lesser acquisition times, which proved to be a benefit for the majority of the patients imaged due to impaired respiratory function. This also proved to be beneficial for obese patients, where uniform fat-suppression can be problematic due to patient size and skin folds. Preliminary investigations utilizing the reconstructed F images indicate that fat distribution and/or quantification analysis may provide additional clinical value. In conclusion, this study shows the promise of replacing existing 2D acquired OP/IP and 3D fat-suppressed T1-weighted imaging with higher spatial resolution 2-point mDIXON protocols. With further protocol refinements, 2-Point mDIXON may enable total examination times that are competitive with present CT body examinations.

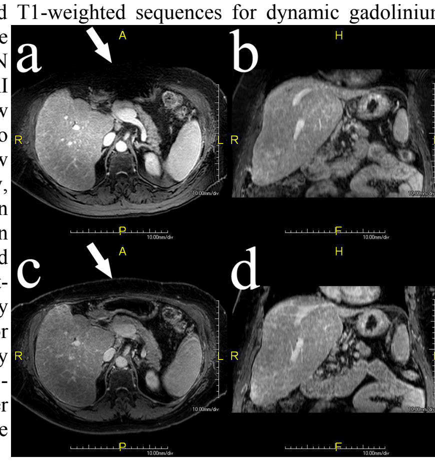

Fig. 3: (a) Post-contrast eTHRIVE acquisition, and (c) equivalent 2-point mDIXON W image. Note the reduced anterior susceptibility artifacts (arrows) and more uniform fat suppression in the 2-point mDIXON W image relative to the eTHRIVE image. (b) and (d) are the coronal reformatted images of the axial eTHRIVE and mDIXON acquisitions, respectively.

References [1]W. T. Dixon, Radiology, 153:189-194 (1984), [2]J. Ma, Magn. Reson. Med., 52:415-419 (2004), [3]Q.S. Xiang, Magn. Reson. Med., 56:572-584.8 (2006), [4]H. Eggers, B. Brendel, G. Herigault, Proc. Intl. Soc. Mag. Reson. Med., 17:2705 (2009)