Improved image contrast and scan efficiency for fat suppressed T1-weighted imaging at 3T with a spin echo two-point Dixon technique

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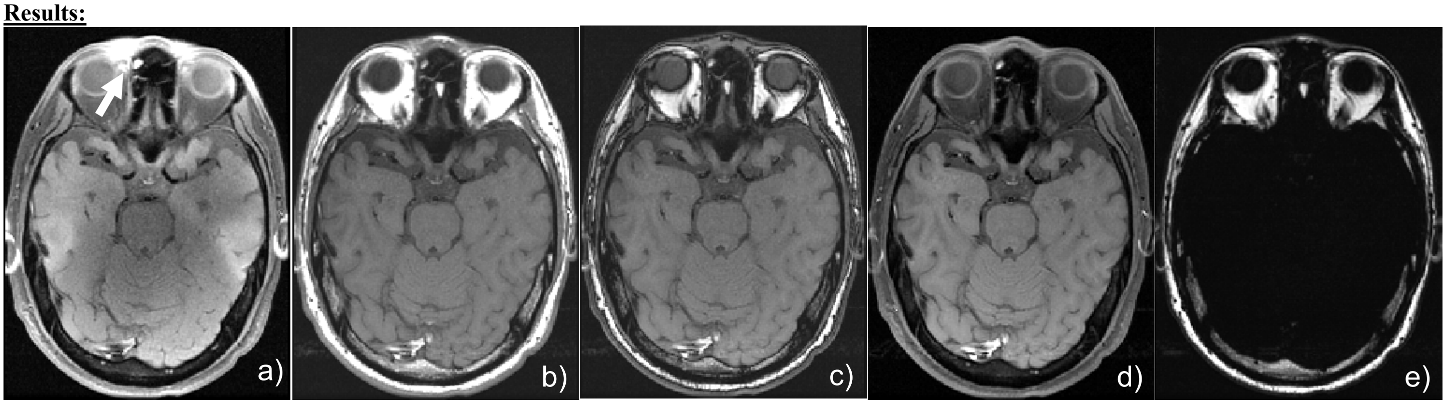
Introduction: Fat suppressed T1-weighted imaging is often an essential component of a clinical MRI exam. Compared to several relatively newer pulse sequences (e.g., spoiled gradient echo, T1FLAIR, FSE), the conventional spin echo (SE) sequence still produces the best T1-contrast and is preferred by many radiologists for certain applications (such as for imaging of head & neck). However, inclusion of the frequency-selective fat suppression (CHESS) pulses in a SE acquisition substantially reduces the number of slices per TR and therefore the overall scan efficiency. More importantly, the image contrast (as well as the signal strength) can be adversely affected from the incidental magnetization transfer (MT) effect of the CHESS pulses [1,2] . At 3 Tesla, the reduced T1 contrast and image quality are further degraded by the prolonged T1-relaxation times and possible dielectric effects. Consequently, the consensus of the radiologists at our institution and at other institutions that we know of is that the T1-contrast of the fat-suppressed SE images is much worse at 3 Tesla than at 1.5 Tesla. Lack of a satisfactory fat-suppressed T1-weighted sequence is currently the main reason for 3 Tesla scanners to be excluded at our institution from certain MR studies (e.g., of the head & neck). The purpose of this work was to develop a new SE two-point Dixon technique to address these limitations of the conventional fat-suppressed SE acquisition. The substantial improvement in scan efficiency and image quality by the new method is demonstrated in vivo.

Experiments and Method: All MR imaging was performed on a 3 Tesla whole-body scanner operating under the HDxt software platform (GE Healthcare, Waukesha, WI). The head and neck of a subject was imaged with an 8-channel phased array head coil using the commercially available SE sequence and the proposed SE two-point Dixon sequence. The scan parameters for both sequences were kept identical and listed as follows: TR/TE = 600ms/MinFull (10ms), RBW = ±25kHz, acquisition matrix = 256x256, FOV = 22cm, pFOV = 0.75, slice thickness/gap = 3.0/0.5mm, total scan time = 3:54min. The SE two-point Dixon sequence was developed from the conventional SE sequence by allowing a time shift of both the readout gradient and the data acquisition window [3]. Two images (one without a time shift and another one with a time shift of 1.15ms) were collected in interleave. These two images thus have water and fat in-phase and 180^{o} out-of-phase, respectively. An image reconstruction software incorporating a previously published phase correction algorithm [4] was implemented on the scanner to produce separate water-only and fat-only images. In comparison to the conventional SE acquisition, the SE two-point Dixon sequence achieved fat suppression through the Dixon postprocessing and without using the CHESS pulses (including the frequency-selective RF pulses and the gradient spoiling pulses). Since the conventional SE sequence requires fat suppression pulses for every echo acquisition, the elimination of these pulses in the SE two-point Dixon sequence provided significant improvement in scan efficiency and avoided the incidental MT and dielectric effects from the CHESS pulses.

Results:



Within the same total acquisition time of 3:54min and for identical scan parameters, the maximum number of slices allowed was 20 and 28 for the conventional SE acquisition and for the Dixon acquisition, respectively. Elimination of the CHESS pulses in the Dixon sequence thus represents a 40% increase in scan efficiency for the protocol used. Figure a) above shows an example slice by the conventional SE sequence. The poor image contrast, local fat suppression failure (indicated by the white arrow), and overall image non-uniformity are all apparent. These image quality issues were commonly observed in our clinical practice before 3 Tesla scanners were excluded from scanning the head & neck patients. Figures b) and c) are the in-phase and out-of-phase images from the same slice location as for Fig a) by the Dixon sequence. The corresponding water-only and fat-only images are shown in Figures d) and e), respectively. Comparison of Fig. a) and Fig. d) illustrates the clear improvement in the image contrast (e.g. between the gray and white matter in the brain), fat suppression, and overall image uniformity.

Discussions: In theory, the increased field strength should result in better image quality by providing better SNR or higher spatial resolution. However, other intrinsic changes (such as T1-relaxation, MT, and dielectric effects) can actually render the images worse at 3 Tesla when compared to 1.5 Tesla or even totally unacceptable. In clinical practice, we find that fat-suppressed T1-weighted imaging of the head and neck is one such area. Using the fast spin echo sequence is a common strategy to compensate for the scan time inefficiency of the SE with the CHESS pulses. However, the multiple refocusing pulses in FSE can introduce mixed T2-weighting and even exacerbate the MT and dielectric effects. In contrast, the proposed two-point Dixon technique maintains the original SE T1-contrast, completely removes the time penalty and MT effect from the CHESS pulses, and provides uniform fat suppression. Similar advantages can be expected at 1.5 Tesla or for other anatomical locations.

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