Optimization of fat suppression for 3.0T DWIBS

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Introduction: Uniform fat signal suppression is often difficult to achieve in a 3.0 Tesla MR system due to magnetic field inhomogeneity and/or B1 inhomogeneity. DWIBS [1] has been proposed as a new method of diffusion MRI that suppresses background signal. In DWIBS, non-negligible fat signals often remain after fat suppression methods are used and the residual fat signals often considerably degrade quality of the images. There are two characteristics about DWIBS in 3.0 Tesla with respect to fat signal suppression: 1) Residual fat signals are increased as the b value is increased. No significant chemical shift artifacts are observed in the images with b value 0. 2) Fat signals are often shifted along phase encoding direction. Residual fat signals often appear at two different positions, as observed in Fig.1. In this study, we have investigated these phenomena and improved fat signal suppression methods for 3.0 T DWIBS.

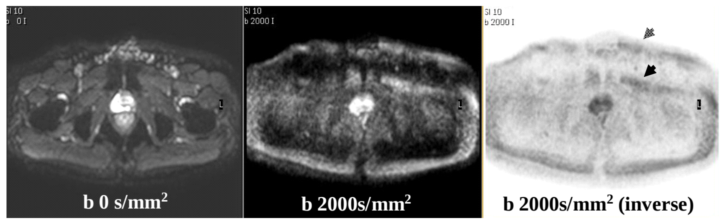

Figure 1 3.0T prostate DWI fat suppression:SPAIR
Residual fat signals can be observed in the image with b 2000 s/mm² although they are not perceptible in the image with b 0 s/mm². There are two distinctive chemical-shift artifacts in the image with b 2000 s/mm².

Methods: We performed the following MR experiments using ten asymptomatic volunteers: Apparent diffusion coefficients (ADC) of visceral fat tissue and those of subcutaneous fat tissue were measured in diffusion weighted images (DWI) with fat signals selectively excited. Also, five types of fat signal suppression methods were compared. The methods we used were STIR, SPAIR, Non preparation method (NP) [2, 3], STIR with SPAIR, STIR with NP. In NP, polarity of slice select gradient was inverted during application of a 90º RF pulse and a 180º RF pulse. Water signals were selectively excited in NP. TI of STIR and that of SPAIR were set to 250ms and 90ms, respectively. We used the following parameters in the DWI experiments: TR 9000ms, TE 80ms, NSA 4, slice thickness 4mm, the number of slices 50, b value 1000 s/mm².

Results: The measured ADC's of visceral and subcutaneous fat tissues were 0.5～0.7mm²/sec and ≦0.1mm²/sec, respectively. They were substantially small. In comparion of the five fat suppression methods, the best fat signal suppression was achieved in STIR with NP, as observed in Fig.2. Other clinical images obtained using STIR with NP are shown in Fig.3.

Discussion: Since ADC's of fat tissue are small, residual fat signals become prominent as b value is increased. The residual fat signals are negligible in the images when b value was 0. Since ADC's of subcutaneous fat tissue are smaller than those of visceral fat tissue, the artifacts that result from subcutaneous fat are more prominent than those of visceral fat. There are two different chemical shift components in fat tissue, i.e. saturated fatty acid (-440Hz) and unsaturated fatty acid (0Hz). This is the reason why chemical shift artifacts were observed at two different positions in Fig.1. There are multiple chemical shift components in fat tissue. Each of them has their own T1 value [4-6]. It was demonstrated that improved water-fat separation could be achieved if these multiple components are considered [7]. We suppose that chemical shift artifacts originated both from saturated and unsaturated fatty acids appeared. Five fat suppression methods were compared in our experiments. Details of these methods are described below: In STIR, as long as an approproate TI are used, unambiguous fat signal suppression can be achieved irrespective of their spectral frequencies. However, as the external magnetic field is increased, a T1 value of CH_2 and that of CH_3 around –440Hz and hence their difference are increased. This gives rise to difficulty to determine the optimal TI [4, 8]. In SPAIR, it is difficult to determine the optimal TI when difference between T1 of CH_2 and that of CH_3 cannot be ignored. Furthermore, these T1 values are varied if local B0 inhomogeneity exists. Since spectrally selective pulses are used in SPAIR, signals from unsaturated fatty acid around 0Hz cannot be suppressed. In NP, fat signals from CH_2 and CH_3 can be suppressed. Even if B0 inhomogeneity exists, performance of fat signal suppression of NP is more stable than that of SPAIR since it uses frequency-selective RF pulses. However, signals of unsaturated fatty acids around 0Hz cannot be suppressed. In STIR with SPAIR, although signals from unsaturated fatty acids around 0Hz are suppressed, the optimal TI is hard to determine due to the difference between T1 of CH_2 and that of CH_3. In STIR with NP, signals both from CH_2 and CH_3 can be suppressed while suppression of signals of unsaturated fatty acids around 0Hz are maintained. Therefore, the best performance of fat suppression can be achieved when STIR with NP is used.

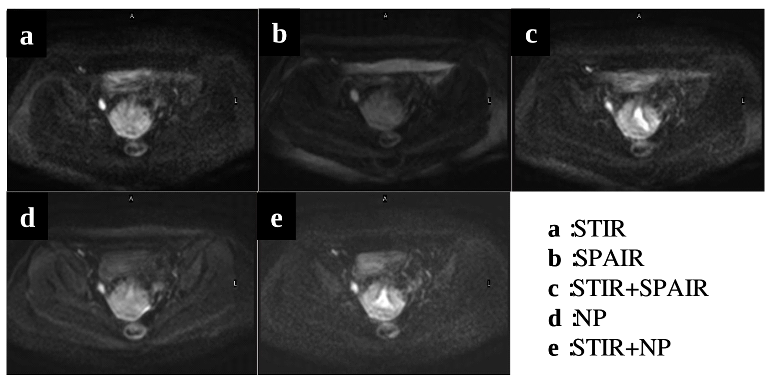

Figure 2 Comparison of five types of fat suppression methods (pelvis DW images with b value 1000s/mm² in 3.0T)

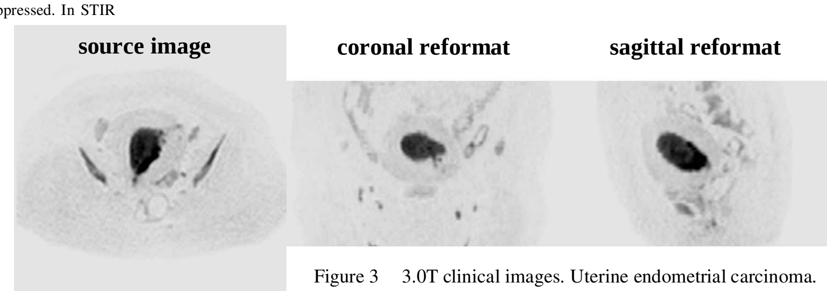

Figure 3 3.0T clinical images. Uterine endometrial carcinoma. Fat suppression : STIR+NP b value 1000s/mm²

Conclusion: It is essential to achieve complete fat signal suppression for 3.0 T DWIBS. However, there are non-negligible differences both in T1 and spetral frequency between saturated and unsaturated fatty acids. Uniform fat suppression may not be achieved if a single fat suppression method is used. Two fat suppresion methods needs to be combined to achieve complete fat signal suppression. In our experiment, uniform fat suppression can be achieved when STIR with NP is used.

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References: [1] Takahara T et al. Radiat Med 2004; 22:275-282. [2] Gomori JM et al. Radiology 1988; 168:493-495. [3] Nagy Z et al. MRM 2008; 1256-1260. [4] Kuroda K et al. MRM 1998; 40:505-510.[5] Delfaut EM K et al. Radiographics 1999; 19:373-382.[6] Mao J et al. MRI 1993; 11:385-393.[7] Yu H et al. ISMRM proceedings 2008; 652.[8] Toshio T et al. JSRT 1997; 53:1647-1656.