Partially Spoiled Dual Echo Steady State Acquisitions (pDESS)

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Introduction. Recently, an analytical solution for the steady state of SSFP sequences with RF phase cycling has been derived [1] and was extended to echo-shifted sequences. Conceptually being straightforward, the theory and effect of partial spoiling is extended to time-reversed steady-state free precession (SSFP-echo, also known under the acronyms PSIF, T2-FFE, CE-FAST). SSFP-echo has found application in diffusion weighted imaging and is of special interest in combination with SSFP-FID as dual echo steady state (DESS) acquisition for joint imaging. We will show that partial spoiling of dual echo steady state (pDESS) acquisitions is beneficial for improved morphological mapping of cartilage.

Methods. From previous work [1,2] it can be inferred that the transverse configurations (after the *k*th RF pulse) of SSFP-FID and SSFP-echo sequences have opposite phase evaluation properties with respect to radiofrequency phase cycling $\phi_k - \phi_{k-1} = k\phi$. The phase of the first echo (ADC1), which forms the SSFP-FID signal (see Fig. 1), must be gauged to the phase of the preceding RF pulse (i.e., $ADC1_{phase} = \phi_k$). This is in contrast to the phase of the second echo, forming the SSFP-echo signal (ADC2), which must be gauged to the proceeding RF pulse (i.e., $ADC2_{phase} = \phi_{k+1}$). Proper ADC phase adjustment enables correct addition of the two echoes as formed with DESS type of sequences. Sample images for depiction of human patellar cartilage were acquired for DESS and pDESS in 3D (128x128x16 matrix size) on a clinical 1.5T scanner (Siemens Espree) yielding 1x1x2 mm resolution. Further DESS and pDESS sequence parameters were: flip angle = 30°, bandwidth = 240 Hz/Pixel, TR = 14.3 ms and TE = 3.75 ms.

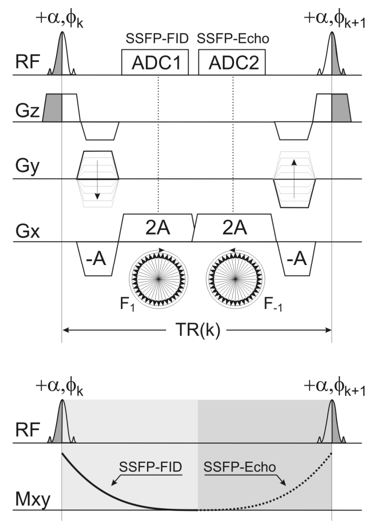

Fig. 1 (top): Partially spoiled dual echo steady state (pDESS) sequence scheme. The difference between consecutive RF phases is linearly incremented. (bottom): The ADC for the two echoes must be gauged to the phase of the corresponding RF pulse .

Results & Discussion. Figure 2 compares the result of a common 3D DESS image acquisition with a partially spoiled one using a partial spoiling increment of $\phi = 10°$. The two sequences have essentially the same image acquisition parameters except for the RF phase increment. If compared to common DESS, partial spoiling results in a very strong attenuation of the signal from the fluid (due to its exceptional long T2), whereas signal intensities for cartilage, fat and other tissues remain unchanged. Although the strong fluid-cartilage contrast is beneficial for assessment of cartilage damage, Fig. 2 clearly indicates a substantial loss in cartilage. As compared to RF and gradient spoiled sequences (SPGR, FLASH) often used for morphological assessment of cartilage, pDESS shows similar contrast but signal-to-noise is increased since transverse components also contribute to the steady state amplitude. From this pDESS might be a superior alternative to SPGR for the assessment of morphological properties of cartilage.

Conclusion. We have successfully demonstrated the combination of partially spoiled SSFP-FID and SSFP-echo to form a dual echo steady-state acquisition after proper phase adjustment (pDESS). Although pDESS might be of limited diagnostic potential, its highly similar contrast to SPGR (FLASH) may turn out to be beneficial for morphological assessment and evaluation of cartilage fine structure allowing for increased resolution from increased SNR.

References. [1] Ganter C, MRM 55 (2006). [2] Ganter C, MRM 56 (2006).

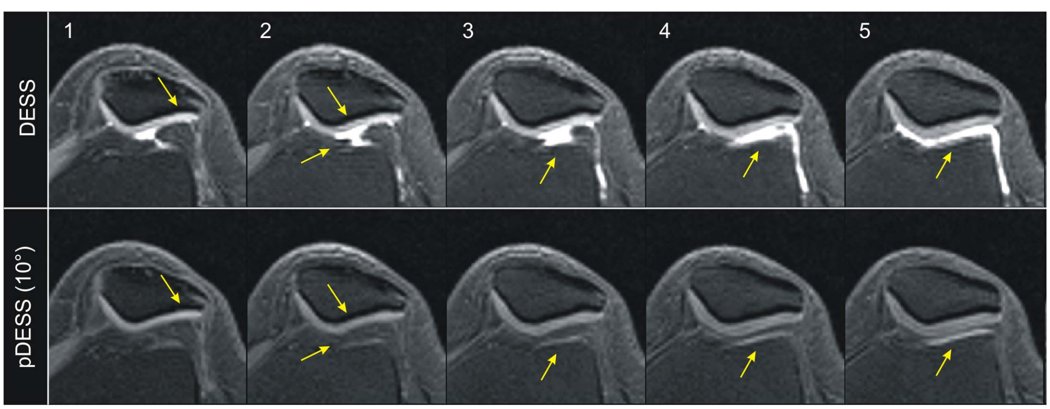

Fig. 2: DESS vs. pDESS. Partial spoiling (ϕ=10°) is very effective for long T2 components such as fluid. DESS shows a strong hyperintense contrast between fluid and cartilage, which is beneficial for assessment of cartilage damage (e.g., fissures). However, partial volume effects and Gibb's ringing may hamper a reliable morphometry of cartilage. As illustrated (yellow arrows), for pDESS, cartilage signal is more homogeneous (1) and there is no Gibb's ringing (2) which might improve segmentation, or partial volume effects may result in a significant loss of cartilage volume, especially with respect to superficial layers (3,4,5).