

Non-contrast Diffusion-weighted MRI for Detection of Synovitis using DESS

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Introduction: Synovitis is frequently observed in osteoarthritis and is characterized by thickening of the synovial membrane and joint effusion. Currently, the gold standard for detecting synovitis is T1-weighted MRI with intravenous contrast, which is not routinely acquired in a standard knee exam. The inclusion of scans that require administration of an intravenous contrast agent adds time, potential toxicities, cost and complexity to the protocol. Using diffusion-weighted imaging it may be possible to create contrast between the thickened synovial membrane and the joint effusion, due to the increased synovial fluid volume. We propose a modified double echo steady state (DESS) sequence, with a diffusion gradient between echoes^{1,2}, for detection of synovitis without the need for a contrast agent.

Methods: We acquired contrast enhanced T1-weighted images and modified DESS images in five patients with synovitis (3 female, 67±9 years) on a 3T MRI system. The modified DESS sequence has primarily T2/T1 contrast in the first echo, with heavier T2 and diffusion weighting on the second echo. Scan parameters included: diffusion gradient=10 cycles/pixel (slice encode direction); echo times = 9 and 43 ms; matrix 256x256; field of view= 16cm, scan time = 5 minutes. While it is possible to observe synovitis in the second echo, due to the diffusion of the synovial fluid, image brightness/contrast must be carefully adjusted such that other image features are not visible (Figure 1). To improve contrast between the synovial membrane and fluid, a hybrid image was created as a linear combination of the echo 1 and 2 images (Figure 2). We carried out simulations to determine the coefficient (β) that nulled the fluid signal, thereby increasing contrast. Specifically, we predicted the fluid signal in the echoes 1 and 2 using two different signal models, the Wu-Buxton signal model (WBSM)³ and extended phase graphs (EPG)⁴, and known values of T1 and T2 relaxation times and diffusivity (3620ms, 767ms and 2.6 $\mu\text{m}^2/\text{ms}$, respectively^{2,5}). The coefficients that null the idealized fluid signal were determined ($\beta_{\text{WBSM}} = 1.41$ and $\beta_{\text{EPG}} = 1.69$). Hybrid images were created for each patient using the coefficient for each model. The contrast ratios (fluid signal/membrane signal) of the T1-weighted contrast enhanced, the WBSM hybrid and the EPG hybrid were compared (lower values = better contrast).

Results: Nine examples of synovitis were examined in the five patients studied. The hybrid approaches were successful at increasing differentiation between the synovial membrane and fluid (Figure 3). The contrast ratios for the T1-weighted contrast enhanced, the hybrid WBSM and the hybrid EPG model were 0.47±0.10, 0.69±0.16 and 0.55±0.18, respectively.

Discussion and Conclusion: A linear combination of the modified DESS echoes results in improved differentiation between the synovial membrane and joint effusion, as compared to the source DESS images. While the contrast ratios for the hybrid models are not as low as that of the T1-weighted contrast enhanced sequence, the synovial membrane is visually discernible. This approach represents an additional advantage of modified DESS that can also be used to assess T2 relaxation times and apparent diffusion coefficient of cartilage^{1,2,6}. With a modified DESS sequence it may be possible to reliably detect synovitis without the need for an intravenous contrast agent.

References: 1) Staroswiecki et al, MRM, 2012; 2) Bieri, MRM, 2012; 3) Wu, JMR, 1990; 4) Hennig, MRM, 2004; 5) Gold, AJR, 2004; 6) Welsch et al, MRM, 2009; **Acknowledgements:** NIH EB002524, AR062068, AR0063643, and CA159992; NSERC PDF; Arthritis Foundation

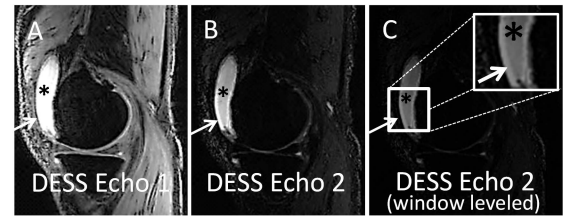


Figure 1: Example of modified DESS echo 1 (A) and echo 2 (B). When window leveled, synovial membrane can be discerned from DESS echo 2 (C). The asterisks indicate synovial fluid; the white arrows indicate synovial membrane.

$$\text{DESS Echo 1} - \beta * \text{DESS Echo 2} = \text{hybrid image with improved contrast between synovial fluid and membrane}$$

Figure 2: Equation used to create a hybrid image that improves contrast between the synovial fluid and membrane for detection of synovitis. β is determined using a WBSM and EPG models.

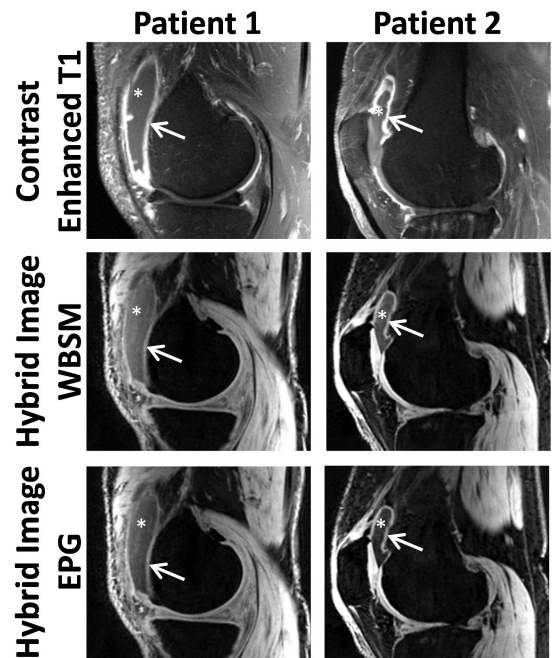


Figure 3: Example images from 2 patients. The synovial membrane can be differentiated from the synovial fluid on the contrast enhanced and the DESS images. Again, the asterisks indicate synovial fluid; the white arrows indicate synovial membrane.