True-SEEPAGE: A Tool for Evaluating Renal Perfusion and Function

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Introduction: The study of renal function using MRI has been performed using contrast agents containing gadolinium (Gd) and sequences such as arterial spin labeling (ASL). However, the use of Gd based contrast agents introduces the risk of Nephrogenic Systemic Fibrosis (NSF), a condition that has been associated with Gd-enhanced MRI in persons with renal impairment. The drawbacks of ASL include patient motion, small quantities of blood flowing into the imaging slice and variations in breath-hold durations leading to image misregistration **(1-2)**. These problems have warranted the need for a new and more efficient non-subtraction sequence; here we present a method called Spin Echo Entrapped Perfusion Image (SEEPAGE) to meet the goals of renal perfusion visualization without the need for Gd-based contrast agents **(2)**. The preparation in this sequence comprised of slice-selective saturation (90 degrees) in the imaging slice, followed by a train of global inversion pulses (180 degrees). The inversion pulses keep the magnetization in the imaging slice close to zero while simultaneously attenuating the inflowing unsaturated spins **(2)**. In a new variant of the technique, a segmented True-FISP imaging module is used to provide qualitative perfusion images of the kidneys.

Materials and Methods: A segmented SEEPAGE-TrueFISP sequence using a 1.5 T scanner (Siemens Espree, Erlangen, Germany) and a 6 channel body coil array is used. The imaging parameters include: TR = 4.1 ms, anterior/posterior phase encoding ordering, base resolution = 128, phase partial Fourier = 5/8, bandwidth = 500Hz/Px, True-FISP flip angle = 50°, and linear reordering. The number of inversion pulses (nInv) varied between 10 and 15 with an inter-pulse spacing (TIP) ranging from 30 ms to 40 ms. In this IRB approved study with written informed consent, volunteers were scanned in axial, coronal and sagittal orientations during complete expiration breath-holds. In order to evaluate perfusion, validation images were obtained where the slice selective saturation pulses at the beginning of the sequence were replaced with global pulses, resulting in complete saturation of all surrounding tissue and blood. The saturation, inversion and imaging blocks were tested separately and in combination with each other to evaluate complete functionality.

Results: The True-SEEPAGE scans using 11 inversion pulses and TIP = 35 ms yielded successful perfusion images. The signal level in the kidneys varied as a function of the inflowing blood in the aorta and hence as a function of the cardiac cycle. As seen in Fig. 5, a validation scan removed most of the signal from the imaging slice (excluding subcutaneous fat).

Discussion: The number of inversion pulses and the inter-pulse spacing are chosen to optimize the blood inflow while preserving its signal and maintaining suppression of the stationary tissue. Following the peak signal of blood in the aorta, the signal of the kidney increases slightly, followed by a decrease in the signal coincident with the blood flow signal decrease in the aorta during diastole. The sequence's efficacy results from the ability of the user to suppress the stationary tissue. The suppression achieved here was not complete (i.e. 100%); therefore, the longer T1 species appear hyperintense. The validation scan, where global saturation pulses are applied, offers 98% saturation; for this reason, we believe that the True-SEEPAGE images represent the true perfusion signal. In the future, non-subtraction True-SEEPAGE images might be able to detect and differentiate different between types of tumors without using a potentially harmful exogenous contrast agent.

References: [1] Fischer A. et al., JMRI 27: 63-70 (2008)
[2] Blamire A. et al., MRM 43: 701-704 (2000)

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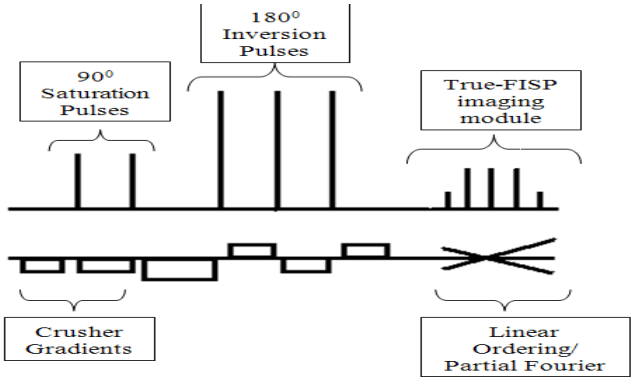

Figure 1: SEEPAGE-TrueFISP Pulse Sequence Diagram.

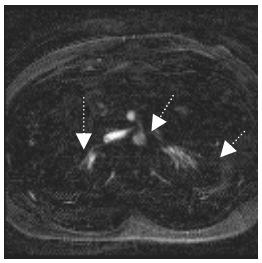

Figure 2: Breath-hold scan, nInv = 11, TIP = 35 ms. Td = 0 ms. The white arrows indicate the signal from the kidneys as a measure of perfusion and flow in the aorta.

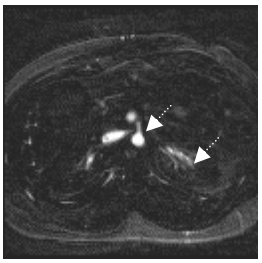

Figure 3: Breath-hold scan, nInv = 11, TIP = 35 ms. Td = 300 ms. The white arrows indicate increased flow in the aorta and higher perfusion signal in the kidneys.

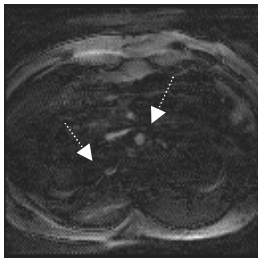

Figure 4: A breath-hold saturation scan with the absence of an inversion pulse module. Td = 0 ms. The white arrows indicate suppressed signal in the kidney tissue and the blood in the aorta.

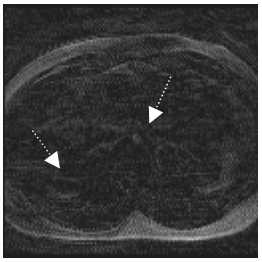

Figure 5: Breath-hold scan, nInv = 11, TIP = 35ms. Td = 0ms. Validation Scan wherein 98% signal from blood and the kidney tissue (not including fat which has a relatively short T1) is suppressed (indicated by arrows).