An optimal view order for cyclically IR-prepped SSFP contrast enhanced MRA

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Introduction

Steady State Free Precession (SSFP) imaging offers the benefit of speed and high signal-to-noise images (1, 2). Its signal dependence on √(T2/T1) requires background suppression in contrast enhanced MRA (3). This can be accomplished by a repeated insertion of an inversion pulse in the train of RF pulses followed by a number of discarded acquisitions (4). Both enhanced blood and background signals vary after inversion pulse, affecting image contrast and artifacts. Here we present an optimal view ordering that minimizes artifacts and maximizes background suppression.

Materials and methods

The optimization criteria for view ordering can be stated as follows. 1) the trajectory in the phase encoding k_yk_z space is smooth to minimize artifacts associated with eddy currents when gradients change from one TR to the next (5); 2) the central portion of k-space is acquired during the background signal nulling to minimize background signal. A view order that satisfies these criteria is illustrated in Fig.1. The k_yk_z space is partitioned into radial fans. The number of k_yk_z-points in a fan is equal to the number of echoes acquired between two inversions. The starting view in each fan (the thick black dots in Fig.1) is chosen such that the center of the fan is traversed at the background nulling point. After reaching the edge of k_yk_z space, views in an adjacent fan are acquired by going back towards the center of k_yk_z space.

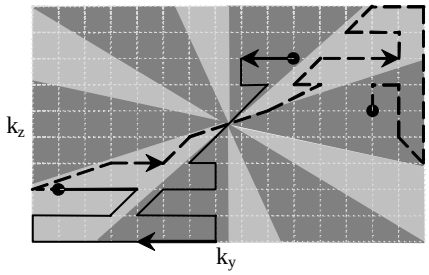

Figure 1: View ordering in k_yk_z space. The first view after each inversion is shown as a thick black dot .

The described view ordering for a magnetization prepared SSFP sequence was implemented on a 1.5T GE Signa CV/i scanner. The pulse sequence calculated the necessary frequency of insertion and the number of disdacqs (executing pulses with data acquisition disabled) based on the prescribed minimal contrast blood signal and maximal background level. A study using standard extravascular contrast agent (ProHance) was performed on four swine (25-35kg) using TR/TE=4.2ms/1.4ms, flip=60°, rbw=±62.5 kHz, coronal FOV=26cm, 2.4mm slice thickness and a 256x160x24 acquisition matrix. Each inversion pulse was followed by 26 disdacqs and 160 actual acquisitions before turning to the next inversion pulse.

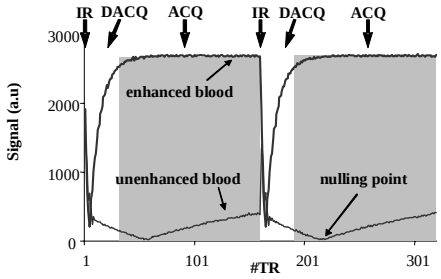

Figure 2: Measured signal of enhanced/unenhanced pig blood. **IR** = inversion pulse, **DACQ**=disdacqs, **ACQ**=acquisition

Results

The measured signal evolutions of contrast enhanced pig blood (T1/T2~40ms/20ms) and unenhanced pig blood (T1/T2~1100ms/280ms) after an inversion pulse are demonstrated in Fig.2 (data were acquired with phase and slice encoding gradients turned off.)

Fig.3a shows a SSFP image of a phantom filled with water containing a tube with Gd doped water. The view reordered background suppressed SSFP image showing this tube can be seen in Fig.3b.

An example of 3D SSFP contrast enhanced MRA is illustrated in Fig.3c, depicting pulmonary vessels and the descending aorta.

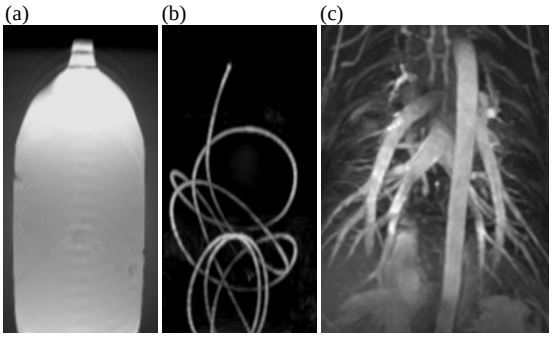

Figure 3: MIP images of phantom (bottle filled with water containing a Gd doped water tube) without (a) and with (b) background suppression. A MIP image of a coronal 3D MRA of the descending aorta and the pulmonary vessels of a pig is shown in (c).

Discussion

We present an optimal view ordering that minimizes artifacts and background. Preliminary data demonstrate that SSFP acquisition for contrast enhanced MRA is feasible using the optimal view ordering. When large FOV is used, banding artifacts may appear due to imperfection in shimming. Further studies are required to develop SSFP type contrast enhanced MRA for clinical applications.

References:

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