VaFA: Replacing CSPAMM

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Introduction: Myocardial tagging is an established approach for evaluating cardiac wall function. While the initial approach to tagging utilized 1-1 SPAMM (Spatial modulation of magnetization)[1], complementary SPAMM (or CSPAMM) [2] is more popular now due to its ability to provide dark blood contrast, and permit faster segmentation of the cardiac cine data. However, by its very nature, CSPAMM requires two separate acquisitions (which can be either in the same breathhold or separate breatholds); misregistration between the two acquisitions can frequently arise, affecting the accuracy of any wall function quantification performed subsequent to the segmentation. Alternate inversion recovery SPAMM (AIR-SPAMM) [3] has recently been presented to overcome this problem; however, since it suppresses the FID, it can only be used to image in systole, and is affected by signal loss. We present an alternative approach, VaFA (Variable Flip Angle), for obtaining SPAMM data with dark blood contrast in a single acquisition. This approach eliminates the issue of misregistration, can be used to image the entire cardiac cycle, and due to the dark blood contrast, can provide similar segmentation benefits as CSPAMM.

Methods: The VaFA approach consists of applying the tagging perpendicular to the phase encode direction. Due to this, the tagging peaks occur in the phase-encoding direction in the frequency domain. Subsequently, a variable flip angle RF pulse scheme is utilized to acquire the various phase-encoded lines such that the center of k-space is acquired with a zero degree flip angle pulse. This approach, hence, yields results similar to CSPAMM, since the DC peak is being minimized. The high-frequency signal of the tag peaks are maintained by this approach and the peaks do not get clipped due to the variable flip angle pulses. A Gaussian weighting scheme was used to set up the RF flip angles over the ky range, as shown in figure 1. The scheme was set up to yield a zero degree flip angle RF pulse at the center of k-space, and 15 degrees flip angle pulse towards the outer region of ky. This scheme was implemented in combination with a 1-1 SPAMM tagging pulse (tag spacing 10 mm) and a segmented FLASH cine sequence on a TIM Trio system (Siemens Medical Solutions, Malvern, PA). For the Gaussian scheme, the weighting factor ranged between 15 and 25. Data was acquired on phantoms and healthy volunteers. Cine tagged data was acquired in humans using single breathhold scans (15 heartbeats), with 13 – 18 cardiac phases data being obtained over this period.

Results: Figure 2 shows the k-space view of 1-1SPAMM, CSPAMM and VaFA tagged cine images acquired on a normal volunteer. The VaFA approach shows the twin peaks corresponding to 1-1 SPAMM, as well as the absence of the DC peak (similar to CSPAMM). Figure 3 shows the signal intensity plot for the center line (kx = 0) from figure 2. Besides the suppression of the DC peak, the plot also shows that the tagging peaks have signal intensity similar to 1-1 SPAMM. The first frame of a tagged short axis cine dataset acquired on another normal volunteer, and the second frame of a long-axis tagged cine dataset are shown in figures 4 and 5 respectively. Black blood contrast is obtained in both views, similar to CSPAMM, and tag lines can easily be visualized

Conclusions: A variable flip angle acquisition over the ky domain, in conjunction with tagging perpendicular to the phase-encode direction, can be used to generate dark blood contrast and obtain tagged myocardium similar to CSPAMM techniques without the need for two separate acquisitions. This VaFA approach can be used as a substitute for CSPAMM to minimize scan duration and image misregistration which can arise during CSPAMM reconstruction.

References: 1. Axel L, Dougherty L, Radiology 1989, 171(3):841-845, 2. Fischer SE, et al. Magn Reson Med 1993, 30(2):191-200, 3. Aletras AH, et al., J Magn Reson 2004, 166:236-245.

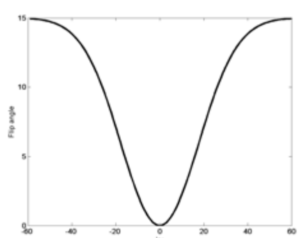

Figure 1.VaFA ky-space RF angle profile

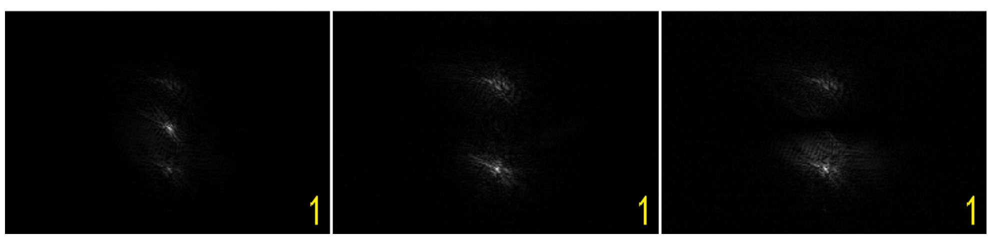

Figure 2. k-space view of VaFA tagging in a human volunteer. Data is from the first cardiac frame. (Left): 1-1 SPAMM, (Center). CSPAMM and (Right) VaFA.

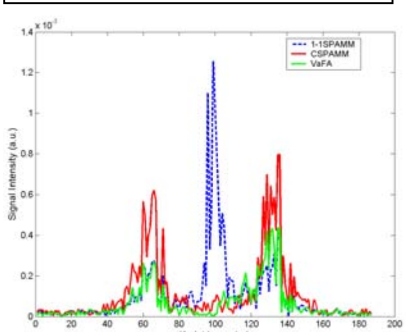

Figure 3. Signal profile for the three techniques in figure 2 (at kx = center).

Figure 4. First frame of short axis cine tagging data from human scan.

Figure 5. Second time step frame of long axis cine tagging data from human scan.