Simultaneous Acquisition Sequence for High Accuracy Whole Liver Perfusion Quantification(SAHA)

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Target Audience: Clinicians and MR physicists interested in hepatic DCE imaging

Introduction: Dynamic contrast enhanced (DCE) MR imaging combined with pharmacokinetic modeling, which can quantify the perfusion and permeability of capillary in liver, is an important technique for malignancy diagnosis, fibrosis stage estimation and hepatic function evaluation [1]. DCE-MRI of liver requires high temporal resolution for accurate arterial input function (AIF) and portal venous input function (VIF) for pharmacokinetic analysis. On the other hand, high spatial resolution is also important for small lesion detection. However, it is hard to achieve both with enough SNR and coverage for whole liver imaging. In this study, considering the AIF&VIF are fast changing while the hepatic parenchyma enhancement is slowly evolving, we propose a DCE acquisition method composed of two 2D acquisitions for high temporal resolution for AIF and VIF, and a 3D acquisition for high spatial resolution whole liver imaging, simultaneously, called SAHA. In this interleaved scheme, the proposed sequence can improve the accuracy of pharmacokinetic analysis.

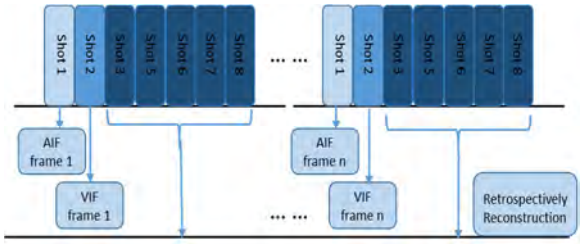

Figure 1 Diagram of SAHA, interleaved 2D and 3D acquisition.

Methods: Sequence Design: The acquisition trajectories for 2D and 3D were Cartesian and golden angle stack-of–stars radial (SoS), respectively. For 2D acquisition, whole k-space was acquired in one shot. For 3D acquisition, all the phase encoding lines in z direction of one radial angle were acquired in one shot. The interleaved pattern (Figure 1) with one shot for AIF, one shot for VIF and 5 shots for liver tissue was implemented with pre-calculation of reasonable temporal resolution. Simulation: Simulations were carried out to compare the pharmacokinetic modeling accuracy of our method with traditional golden angle stack-of-stars radial (Golden angle SoS). A one-compartment two-input Van Beers model $\frac{dC_t(t)}{dt} = k_{1a}C_a(t) + k_{1p}C_p(t) + k_2C_t(t)$ [2] was employed. AIF was generated by $C_a = \sum_{n=1}^{2} \frac{A_n}{\sqrt{2\pi}\sigma_n} e^{\frac{-(t-T_n)^2}{\sigma_n^2}} + \frac{\alpha e^{-\beta t}}{1+e^{-s(t-\tau)}}$ with parameters: A_1=8.09 mM/min, A_2=330 mM/min, T_1=0.17 min, T_2=0.365 min, σ_1=0.0563 min, σ_2=0.132 min, α=1.05/min, β=0.1685/min, s=38.078/min, τ=0.483/min; and VIF by $C_p(t) = D\sum_{n=1}^{2} A_n e^{-K_n(t-t_0)}$ with D=0.2 mM/kg, A_1=1.759 mM/L, A_2=6 mM/L, K_1=1.77/min, K_2=0.0268/min [3]. A set of model parameters were fixed with k_{1a} =32.7ml/min/100g, k_{1p} =146.2ml/min/100g, k_2 =3.315/min to calculate the reference liver tissue curve. For the SAHA, the curves were sampled to temporal resolution 1.7s for AIF and VIF; 7.0s for liver (same as the in-vivo experiment). For conventional Golden angle SoS, the temporal resolution was set to 4.8s for AIF, VIF and liver tissue [4]. The simulation was repeated 5000 times with Guassian noise independently added each time. Simulations with different SNR levels ranging from 50 to 100 with increment of 10 were carried out. Signal level was defined as the maximal value of liver tissue enhancement. Since the parameter of arterial perfusion k_{1a} was reported most indicative for fibrosis stage [2], the mean and standard deviation of k_{1a} were compared between SAHA and Golden angle SoS. In-vivo Experiments: One healthy volunteer (male, 25 years old) was scanned with the proposed sequence on a 3T whole body scanner (Achieva TX, Philips Healthcare, Best, The Netherlands) with a commercial cardiac-torso array 32-channel coil (Philips). The scan parameters are: TR/TE=3.12/1.4 ms, FA=10°. The resolution for 2D and 3D images was 3×3×5 and 1.5×1.5×3 mm^3 respectively. Immediately after the scan started, 0.2ml/kg Gd-DTPA (Bayer, Germany) was injected intravenously at 2 mL/sec and followed by a 15 mL saline flush. The 2D images were reconstructed online and 3D images were retrospectively reconstructed using iGRASP [4] algorithm with 21 spokes per frame. The effective temporal resolutions for AIF, VIF and liver tissue are 1.7s, 1.7s, 7.0 s, respectively.

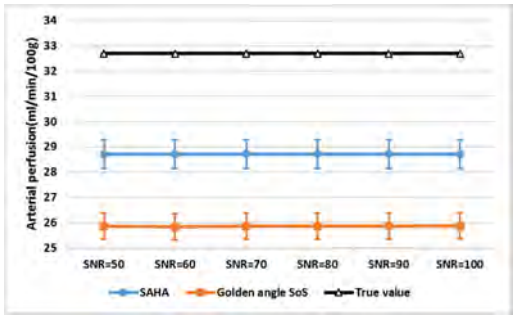

Figure 2 Comparison of the mean and standard deviation (bars) of SAHA and Golden angle SoS.

Results: In simulation, SAHA shows lower bias and similar standard deviation in all levels of SNR comparing with Golden angle SoS (Figure 2). Two sets of DCE images according to the arterial bolus arriving and washing out time were shown in Figure 3.

Discussion and Conclusion: In this study, the simulation results demonstrated that higher temporal resolution AIF&VIF provided higher fitting accuracy. The in-vivo experiment has demonstrated the feasibility of simultaneous acquisition of high temporal resolution 2D images and high spatial resolution 3D images.

Reference: [1] W Lin, MRM, 2008. [2]B Chen, Eur Radiol, 2012. [3]H Chen, MRM, 2011. [4] L Feng, MRM, 2014.

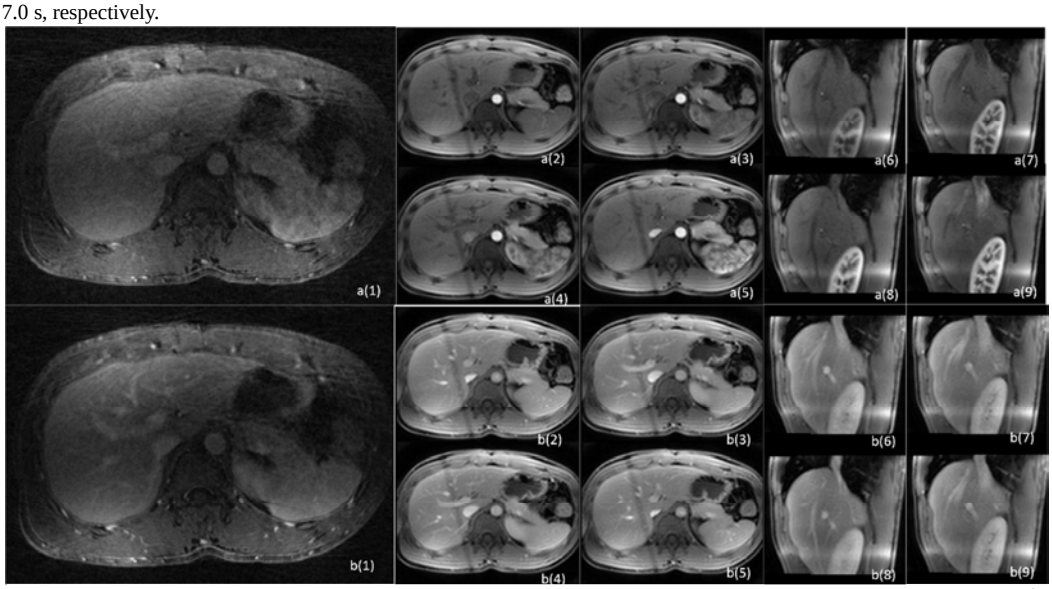

Figure 3 The upper panel (a) is arterial bolus arriving time. The panel below (b) is washing out time. Image 1 is 3D image for tissue, Image 2-5 are 2D images for AIF and Image 6-9 for VIF.