Dark Blood bSSFP Imaging Using Magnetization Prepared Random Velocity Encoding

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Introduction: Flowing blood appears hyperintense in bSSFP due to inflow of fresh magnetization and refocusing of spins which have left the imaging slice (1). While sometimes useful, bright blood can hinder examination of the vessel wall and can cause artifacts. Recently, two methods for obtaining steady state dark blood bSSFP images have been proposed (2,3). Both lengthen the repetition time (TR >= 11 ms) which increases scan time and exacerbates banding artifacts. Here we present a new dark blood (DB) bSSFP method based on periodic application of bipolar velocity encoding gradients along different axes.

Methods: The bSSFP magnetization is periodically stored along the Z-axis using an α/2 pulse (4); any residual transverse magnetization is spoiled (fig 1a). Then, black blood preparation (BBP of figure 1a, as shown in 1b or 1c) is performed. The applied velocity encoding imparts phase in proportion to velocity. Randomizing the amount of velocity encoding (gradient first moment) is necessary to suppress all velocities similar to the need to increment phase in RF spoiling. Simulations including inflow and outflow effects, magnetization storage, BBP (10 readouts per BBP) were performed using Matlab (MathWorks, Natick, MA) assuming plug flow (10 velocities tested; range 13-125 cm/s). Phantom imaging (TR = 5.8 ms, 10 reads per BBP) consisted of imaging a doped water bottle along with two tubes with water flowing in opposite directions (5 velocities tested; range 53-126 cm/s) in a 1.5 T MR scanner (Siemens Espree, Erlangen, Germany). Axial images in the abdomen of an asymptomatic human volunteer were acquired for in-vivo testing (TR = 5.2 ms, 16 reads per BBP). First moments in simulations and experiments corresponded to VENC ranges of 3 to 60 cm/s. Specific results at 17 cm/sec (simulation; Fig 1d-f), 4cm/sec (phantom; Fig 1h) and 3cm/sec (in-vivo; Fig 1j) are presented.

Results: Good flow suppression over the velocity ranges simulated and tested in phantoms was observed. Simulation results for flowing spins (v = 25 cm/s) are shown in figures 1d. Suppression by 99.5%, 96.3%, and 95.7% are achieved for π radians off-resonance, on-resonant, and average over all dephasing angles respectively. Effects on stationary spins are shown in fig 1e. On-resonance spin signal is reduced by 24.3% due to BBP. Fig 1f shows on-resonance signals through time. On-resonance flowing spin signal to stationary tissue ratio is reduced from 176% to 8.6% after BBP. Phantom results (v = 126 cm/s) are shown in figures 1g (no BBP) and 1h (BBP) and signal changes due to BBP are given in the table below:

BBP Variant	Flow Tube 1	Flow Tube 2	Bottle
Non-refocused (1b)	-100%	-100%	-29%
Refocused (1c)	-100%	-97%	-23%

Human in vivo imaging results with normal bSSFP and DB bSSFP (with refocusing) are shown in figures 1i and 1j. Note the suppression of through plane and in plane flowing blood (arrows).

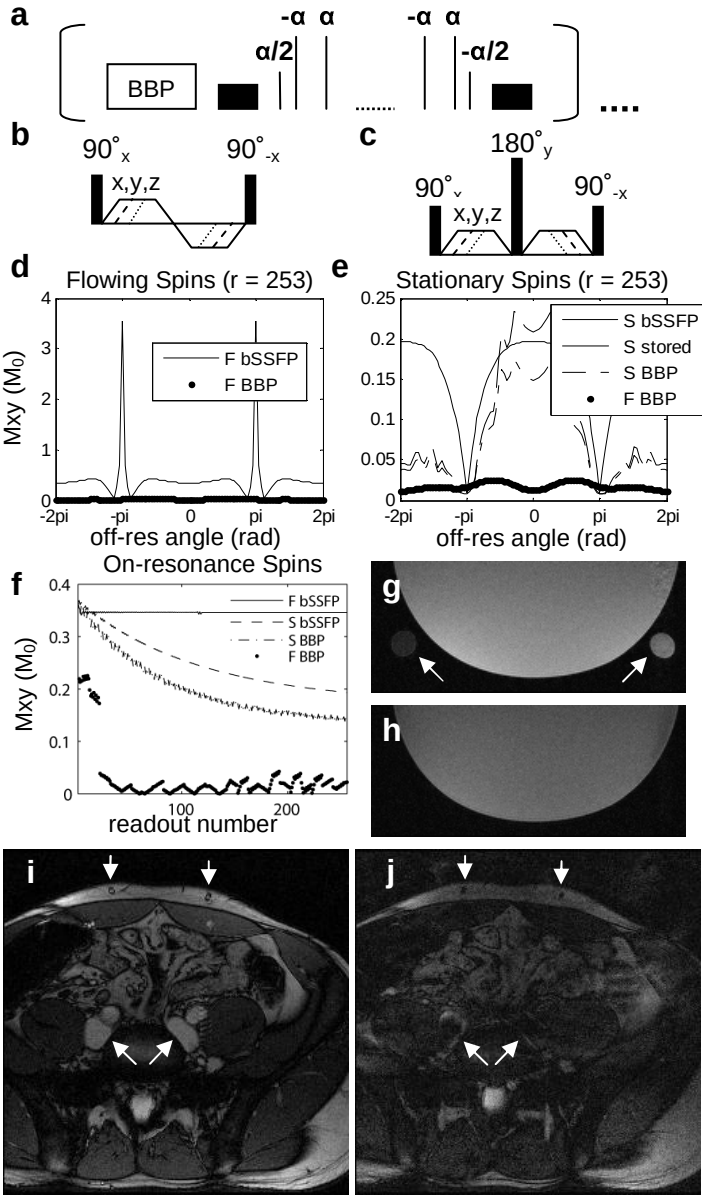

Fig. 1. (a) DB bSSFP sequence diagram. Black boxes represent spoiling gradients. **(b)** Non-refocused and **(c)** refocused velocity encoding schemes. Simulation results (steady state) with and without BBP for **(d)** flowing spins (F) and **(e)** stationary tissue (S; flow with BBP shown for comparison). **(f)** On-resonance signals through time. Note suppressed flow signal (F BBP) compared to stationary spin signal (S BBP). Phantom imaging results **(g)** stored bSSFP (arrows point to flow tubes) and **(h)** DB bSSFP. Human imaging results **(i)** bSSFP and **(j)** refocused DB bSSFP (arrows point to vessels).

Discussion: The results demonstrate the ability to suppress signal from flowing spins in a short TR bSSFP sequence. A much smaller T2 decay dependent signal loss in stationary spins is incurred during velocity encoding. The α/2 pulses used for magnetization preparation cause signal loss above π radians (fig 1e). The signal fluctuations for off resonant spins are the origin of the ghosting from fat tissue seen in the in vivo imaging results (1j).

Conclusion: A new dark blood TrueFISP technique is described. These studies show that periodic magnetization preparation with random velocity encoding can lead to suppression of both through plane and in plane blood flow in TrueFISP.

References: **[1]** Markl M. et al., MRM. 50: 892-903 (2003) **[2]** Lin H.-Y. et al., JMRI. 24: 701-707 (2006) **[3]** Lin H.-Y. et al., JMRI. 25: 1299-1304 (2007) **[4]** Scheffler K. et al., MRM. 45: 1075-1080 (2001)