CAIPIRINHA-SSFP with improved banding artifact performance

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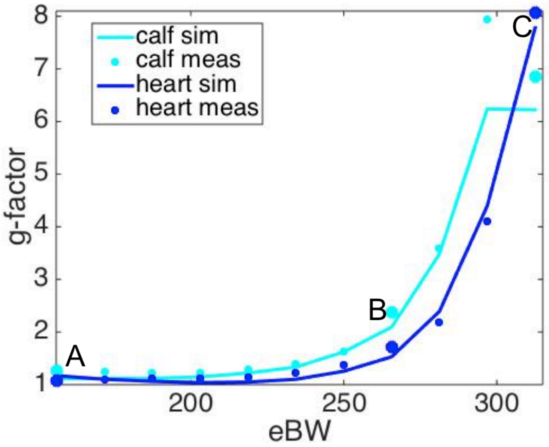
<u>TARGET AUDIENCE</u>: Researchers interested in using CAIPIRINHA-SSFP at high field strengths or areas of the body with significant field inhomogeneity.

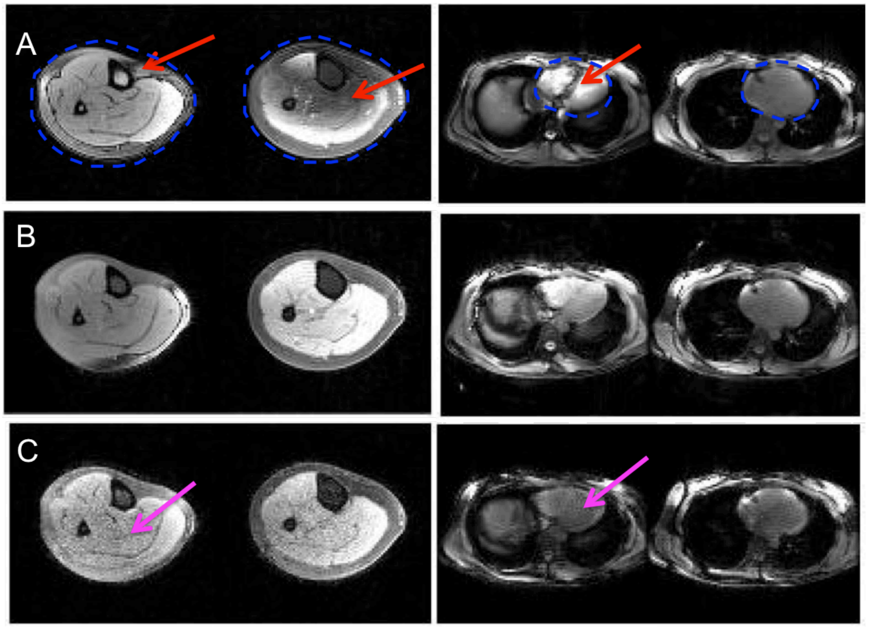
<u>PURPOSE</u>: CAIPIRINHA-SSFP is a simultaneous multislice (SMS) imaging technique previously demonstrated for two-slice cardiac MRI at 1.5T [1]. A major limitation of CAPIRINHA-SSFP is the reduction in the size of the usable SSFP pass-band, which becomes more prominent with increased off-resonance at higher field strengths [2]. Here we demonstrate that CAPIRINHA-SSFP with a phase increment less than ±π/2 allows for a flexible tradeoff between the available bandwidth and noise amplification. For two-slice SMS MRI at 3T, we demonstrate a 70% increase in the effective passband at the cost of a 60-80% increase in average g-factor over the region of interest (ROI), compared to traditional CAIPIRINHA-SSFP.

<u>METHODS</u>: ***RF pulse:*** SMS excitation was achieved with a dual-band, cosine-modulated, Hamming-windowed sinc (0.64 ms, TBW = 4, slice thickness = 1 cm, slice spacing = 4 cm). A phase of ±θn was added to the modulation functions for slice 1 and slice 2 respectively at each phase encode n to create a θ/π FOV shift between the two slices. Note that Ref [1] used a fixed θ = π/2. ***Experiments:*** Experiments were performed on a 3T scanner (EXCITE HDxt, GE) using 8-channel calf and cardiac coils. Imaging Parameters: balanced SSFP, TR = 3.2 ms, TE = 1.5 ms, and matrix size = 96x96. In-vivo calf and heart images were obtained with FOV shifts of 0% to 50% in 5% increments. Single slice reference scans without added RF phase were obtained to calculate coil sensitivity maps and to calculate the expected g-factor for arbitrary FOV shifts. Images acquired without RF were collected to calculate the receiver noise covariance matrix. ***Analysis:*** Effective bandwidth (eBW) was defined to be the spacing between signal nulls in the dual-band SSFP steady-state magnetization profile, i.e. $eBW = \left(\frac{1}{TR}\right)\left(1 - \frac{\theta}{2\pi}\right)$. After using SENSE rate-2 reconstruction, average g-factor value was calculated over the calf or the heart ROI [3].

<u>RESULTS and DISCUSSION:</u> **<u>Figure 1</u>** shows the tradeoff between g-factor using real (SMS) and simulated (combined single-slice) data. **<u>Figure 2</u>** shows separated images with three FOV shifts.



<u>Figure 1</u>. Average g-factor vs. effective bandwidth for simulated and real data. The points A, B, and C correspond to the images shown in A, B, and C of **<u>Figure 2</u>**.



<u>Figure 2</u>. Separated SMS in-vivo images FOV shifts of (A) 50%, (B) 15%, and (C) 0%. The ROIs are identified by a blue dashed boundary. As expected, there is significant banding artifact in A (red arrows) and significant noise amplification in C (purple arrows).

These data indicate a clear tradeoff between eBW and g-factor for different FOV-shifted SMS images. A FOV shift of 50% in **<u>Fig 2A</u>** has significant banding in both calf and heart, while no FOV shift in **<u>Fig 2C</u>** results in a poorly separated image due to g-factor losses. **<u>Fig 2B</u>** shows a preferred tradeoff with a FOV shift of 15% where banding artifacts are minimal with an 80% and 60% increase in g-factor for calf and heart respectively. Point C in **<u>Fig 1</u>** shows that at no FOV shift, the g-factor is 20% higher in heart than in calf while no significant g-factor differences are seen at higher FOV shifts. In addition, it is interesting to note calf g-factor at a 5% shift (corresponding to eBW = 296) is higher than no shift at all (eBW = 312).

<u>CONCLUSION:</u>

We have demonstrated that a FOV-shift of 50% used in SSFP-CAIPIRINHA at 1.5T is not always ideal at 3T. Different FOV-shifts may offer a better tradeoff between eBW and g-factor depending on the application. Here we showed an example where a FOV shift of 15% offers a 70% increase in eBW at the expense of a 60-80% increase in g-factor.

<u>REFERENCES:</u>

[1] Stäb, MRM 65(1):157-64, 2011 **[2]** Schär, MRM 51(4):799-806, 2004 **[3]** Pruessmann, MRM 42(5):952-962, 1999