# Contrast Enhancement for SSFP Angiography with Signal Compensation and Compressed Sensing

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**Introduction:** Magnetization-prepared balanced-SSFP methods can produce flow-independent angiograms without contrast agents through segmented, centric k-space acquisitions [1,2]. Because the T2-prepared contrast gradually decays to the lower SSFP contrast, signal levels vary across k-space [3]. More frequent preparation improves the captured contrast by shortening the readout clusters, but it prolongs the scan time. Instead, we propose to enhance the contrast and resolution without scan-time penalties by compensating for the signal decay, and recover the vessels in sparse angiograms with compressed sensing (CS) [4].

**Methods:** The major background tissues in the extremities are fat and muscle. While alternating repetition time SSFP [4] suppresses fat, T2-preparation with a BIR-4 pulse reduces the muscle signal [5]. Because the generated contrast is transient, phase encodes have centric ordering [6] and the T2-preparation is repeated prior to the collection of each k-space segment [2].

Fig. 1 shows that vessels contribute more heavily to high-spatial-frequency data (e.g., $k_r > 0.5$) than muscle. Therefore, the blood signal can be increased by compensating for its decay in k-space, while the muscle signal remains relatively constant. In turn, this enhances the contrast and prevents image blurring. Although the noise is also amplified, the sparsity of angiograms allows us to recover the blood signal with CS [4].

**Results:** Fig. 2 displays regular and compensated lower-leg images collected at 1.5 T with 19.2-cm FOV, 1x1x1-mm$^3$ resolution, TR=4.6 ms, and 80-ms T2-prep. Fully-sampled data with number of segments (N)=(4,8,16) and scan times of $T_{scan}$=(88,104,137) sec were reconstructed, along with under-sampled data with factors of R=(1,2,4), N=(4,16,22), and $T_{scan}$=88 sec each. In all cases, the proposed strategy improves contrast and resolution, enhancing the depiction of the vasculature. The measured improvements in blood/muscle contrast with compensation are listed in Tab. 1.

**Conclusion:** The effect of magnetization-prep can be enhanced by compensating for the signal decay and exploiting image sparsity. This strategy achieves significantly improved contrast (up to 48%) with shorter scan times and lower accelerations.

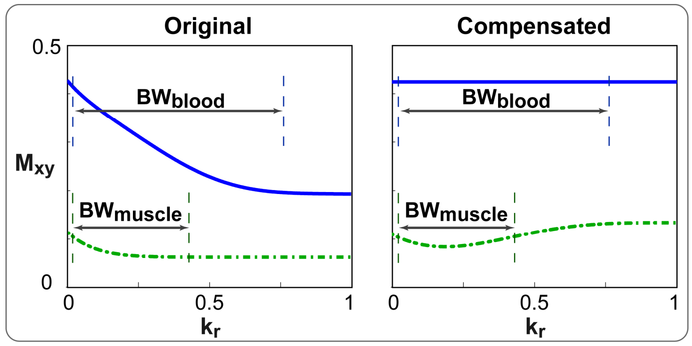


**Figure 1.** Blood (T1/T2=1200/250 ms) and muscle (870/47 ms) signals after T2-prep as a function of k-space radius. The initial blood/muscle contrast of ~5, decays to ~3 in steady-state. The frequency extents (BW, illustrative) are also shown. Vessels have higher frequency content than muscle. Hence, the blood signal can be increased by compensating for its decay, while the muscle signal remains roughly the same.

| Fully-sampled | N = 4 | N = 8 | N = 16 |
|---|---|---|---|
| Regular | 3.02 | 3.30 | 3.55 |
| Compen. | 3.96 | 4.08 | 4.50 |
| % Imp. | 47.8% | 37.0% | 26.9% |

| Under-sampled | R = 1 | R = 2 | R = 4 |
|---|---|---|---|
| Regular | 2.67 | 3.39 | 3.96 |
| Compen. | 3.96 | 4.60 | 4.70 |
| % Imp. | 47.8% | 35.9% | 18.9% |

**Table 1.** Blood/muscle contrast in regular and compensated (with CS) source images. The largest improvement with compensation is for smaller N and R. The compensated contrast for N = 4 is higher than the regular contrast for N = 16, although N = 16 has 56% longer $T_{scan}$.

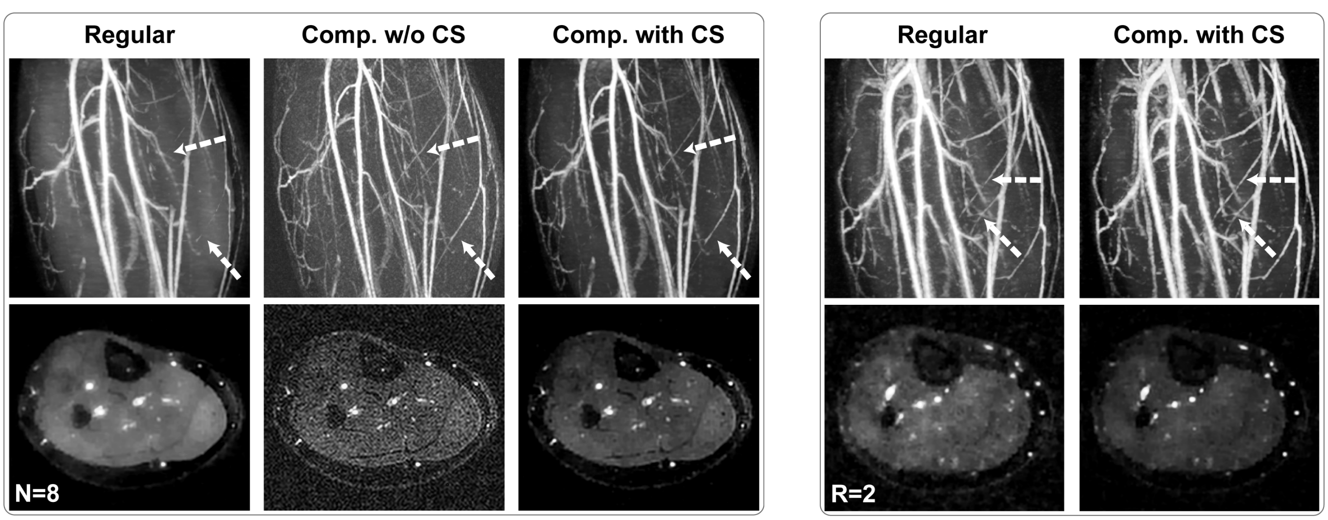


**Figure 2.** MIPs and axial images of regular and compensated (without and with CS) reconstructions, from fully-sampled (N=8, on the left), and under-sampled (R=2) data. The compensated images with CS are sharper and have superior background suppression.

**References:**
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5. Nezafat, 14th ISMRM, p.596, 2006.
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