Improving Dynamic Contrast Enhanced (DCE) Magnetic Resonance (MR) Perfusion Measurements by Appropriate Selection of Image Acquisition Parameters

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INTRODUCTION

- DCE MR imaging provides a linear relationship between signal intensity and [contrast agent (Gd-DTPA)] [1]
- Clinically useful perfusion information can be derived (*i.e.*, CBF, CBV, etc.)
- Con: Gd passage through white matter (WM) and grey matter (GM) produce low signal intensity difference ($S_{contrast} - S_{baseline} = \Delta S$), affecting precision of measured perfusion information
- Improving precision of perfusion measurements can be done by
  1) Increasing *ΔS*
  2) Decreasing signal noise

HYPOTHESIS

Brain tissues can be modeled by the SPGR sequence and MR relationships to appropriately select a scanning parameters that will maximize *ΔS* and minimize signal noise, to improve perfusion measurements

METHODS

Part I – Increasing ΔS

- Modeling the SPGR equation [2]:

$$S(t) = M_o \frac{1-e^{-TR \bullet R_1(t)}}{1-\cos(\alpha)\cdot e^{-TR\bullet R_1(t)}} \cdot \sin(\alpha) \cdot e^{-TE\bullet R_2^*(t)}$$

- WM was simulated (Fig 1), varying TR & α

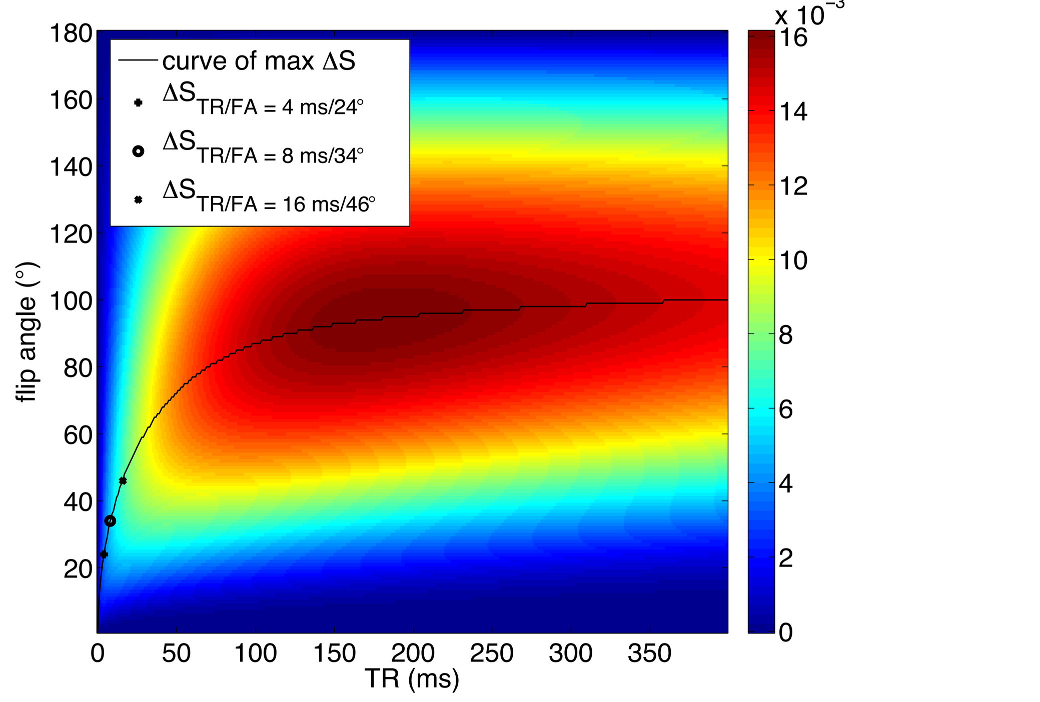

Fig 1: ΔS(TR, α) for WM using the SPGR equation. Constant parameters: TE = 1.4 ms, T_1 = 1.1 s, T_2 = 70 ms, r_1 = 3.3 [Hz/mM], r_2 = [Hz/mM], [Gd in arterial blood] = 8 mM. The maximum ΔS curve shows the optimal pairs of TR and α.*

Phantom Experiment

- Dissolved agarose and Gd, with submerged polyethylene & silicone tubes mimicked brain tissue and blood vessels, respectively
- Phantom was scanned with saline and then with 8 mM Gd injected at TR values of 4, 8, & 16 ms; most other parameters held constant

Human Experiment

- An acute stroke patient was scanned with DCE MR using TRICKS [3] (ethics approved)
- Scans were acquired at two TR's during the single injection for *ΔS* comparison

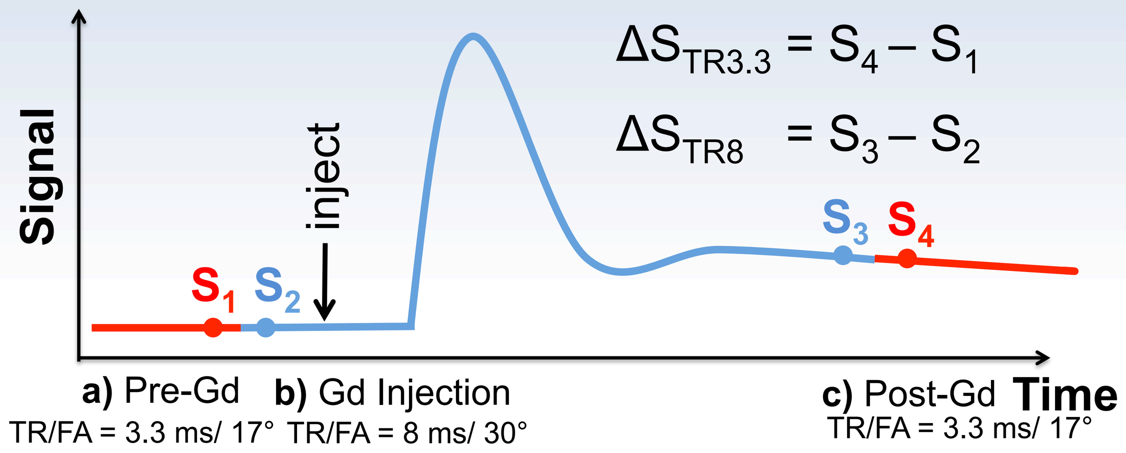

Fig 2: The sequence of scans acquired pre- and post-Gd injection. ΔS is calculated by subtracting the baseline signal from the the post Gd signal (rather than peak signal) for direct comparison between $\Delta S_{TR3.3}$ and ΔS_{TR8}

Part II – Decreasing Signal Noise

- The relation $SNR \propto 1/\sqrt{BW}$ [4] was tested
- A spherical phantom containing dimethyl silicone fluid, Gd, and colorant was scanned at different BW values
- The SPGR sequence was used, at three sets of TR/BW: 8 ms/25 kHz, 16 ms/25 kHz, and 16 ms/ 6.41 kHz
- Lower BW requires longer readout (Fig 3)

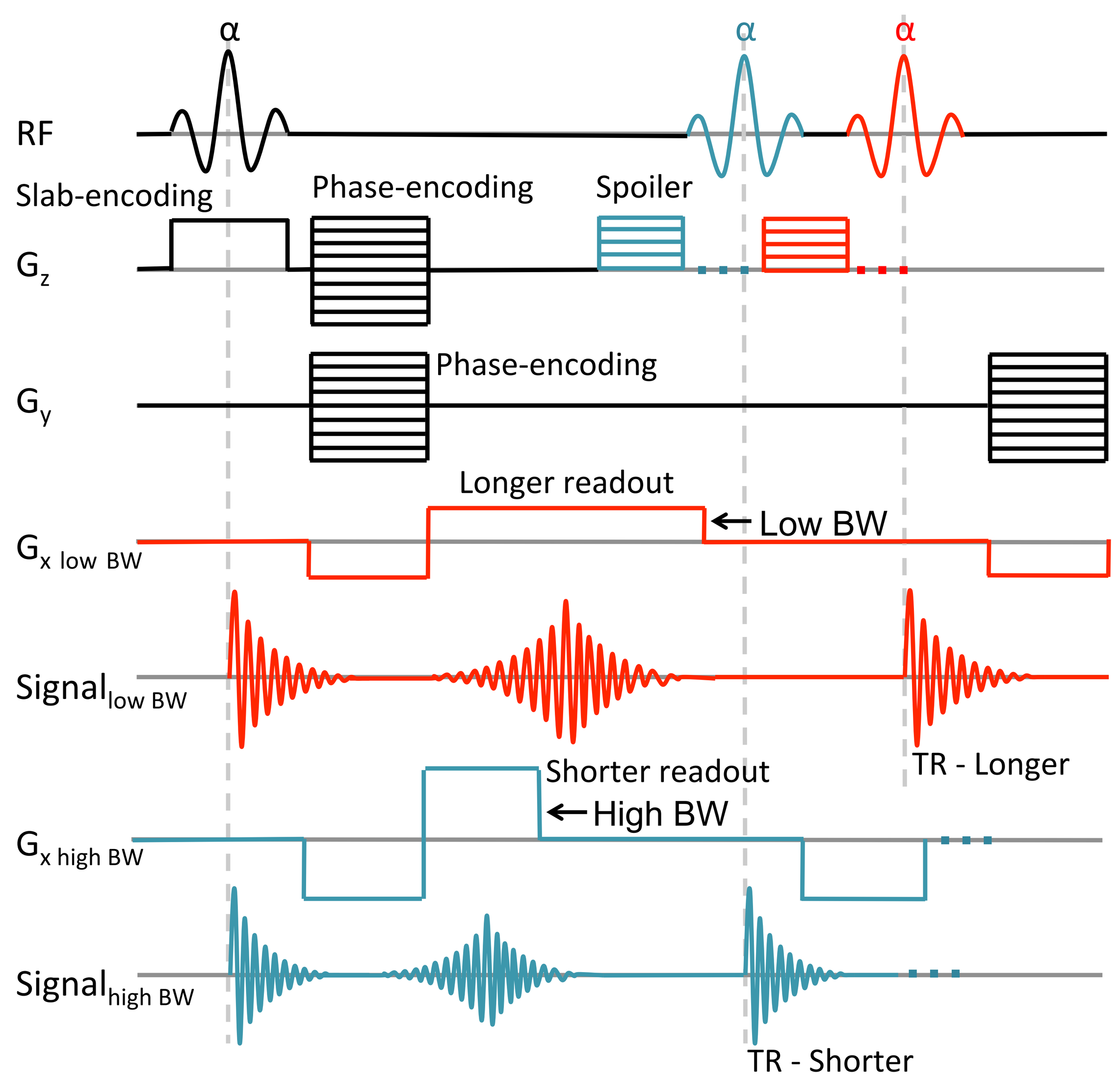

Fig 3: The 3D SPGR pulse sequence diagram. Lower BW values require longer readout times and longer TR (red). Higher BW allows for shorter readout times and shorter TR (blue). For a given TR, there is a minimum BW.

Imaging Acquisition

- Imaging was performed using a 3T MR scanner, with a 32-channel head coil

RESULTS

Part I – Increasing ΔS

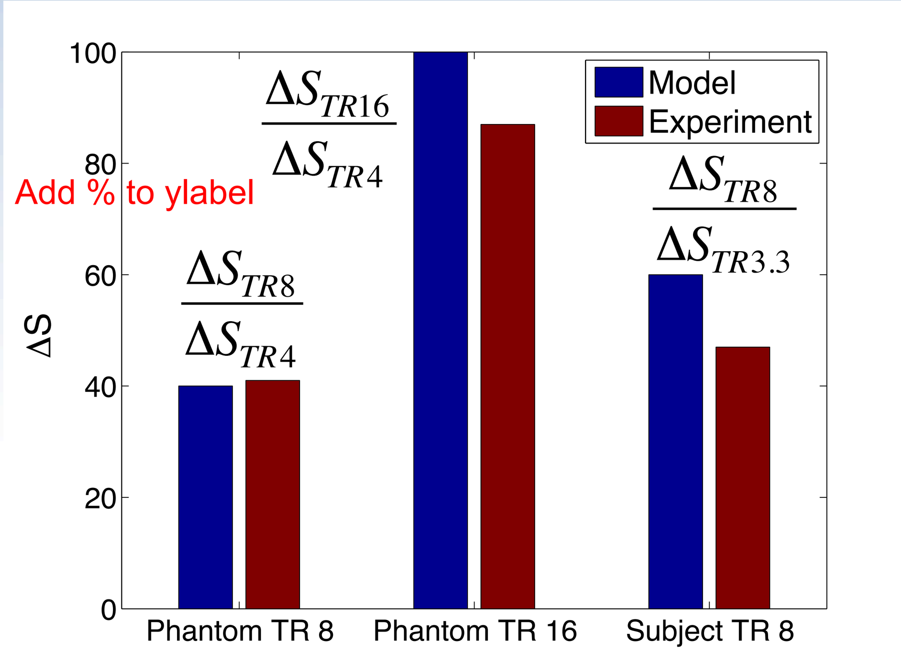

Fig 4: Comparison of the percent increase in ΔS when longer TR is used compared to TR of 4 ms for phantom, and TR of 3.3 ms for patient. Model and experimental values are similar.

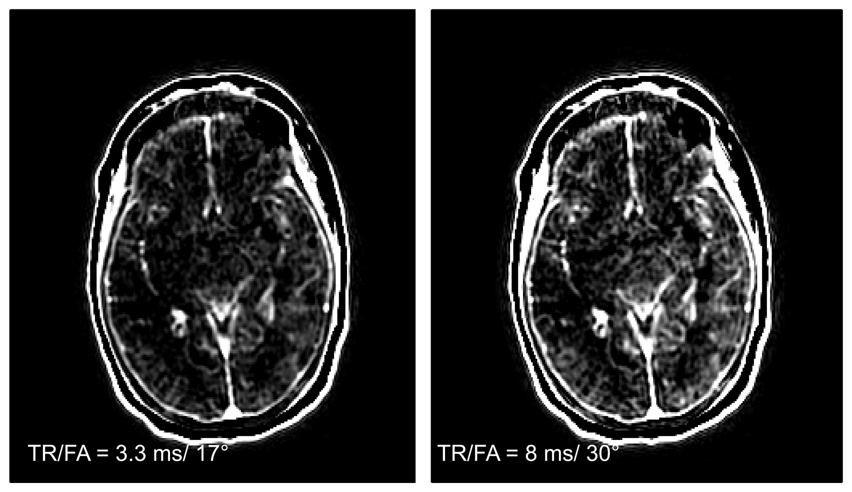

Fig 5: ΔS of one slice of patient data, at the two sets of parameters scanned. Increased signal and physiological differences within WM and GM can be visually observed at TR/FA or 8 ms/ 30°.

Part II – Decreasing Signal Noise

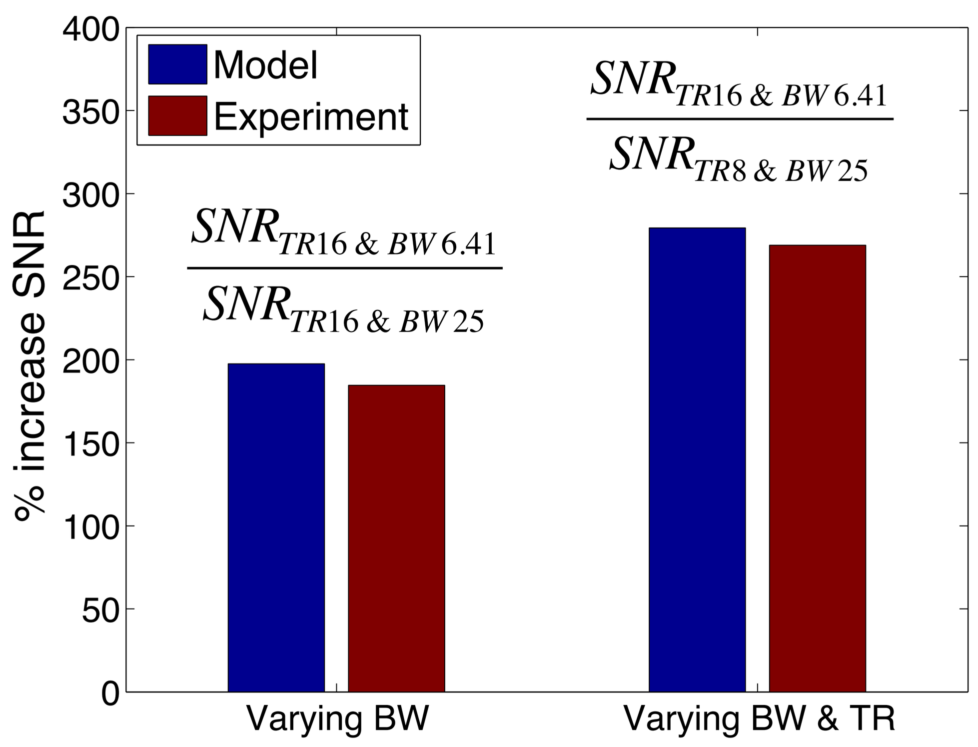

Fig 6: Percent increase in SNR by varying BW and/or TR, calculated from mid-volume circular ROI. 24 time phases were scanned at a TR of 8 ms and 12 times phases scanned at a TR of 16 ms.

DISCUSSION

Part I – Increasing ΔS

- Phantom images scanned at a TR of 8 ms and 16 ms both showed increases in ΔS (compared to TR of 4 ms) that supported modeled values (Fig 4)
- Stroke patient images visually and quantitatively showed increased signal difference observed in WM and GM regions using TR of 8 ms compared to TR of 3.3 ms (Fig 5)
- TR values closer to the 'optimal range' as modeled (Fig 1) result in higher ΔS with contrast agent injected

Part II – Decreasing Noise

- Lowering BW resulted in the theorized increase in SNR
- Choosing longer TR and minimum BW resulted in the highest SNR increase

CONCLUSIONS

- Modeling WM with the SPGR equation provided a curve with sets of optimal TR and flip angle values to increase *ΔS*
- Tests validated that decreasing BW increased SNR
- An appropriate combination of scanning parameters can be chosen to improve DCE MR perfusion measurements (Fig. 7)

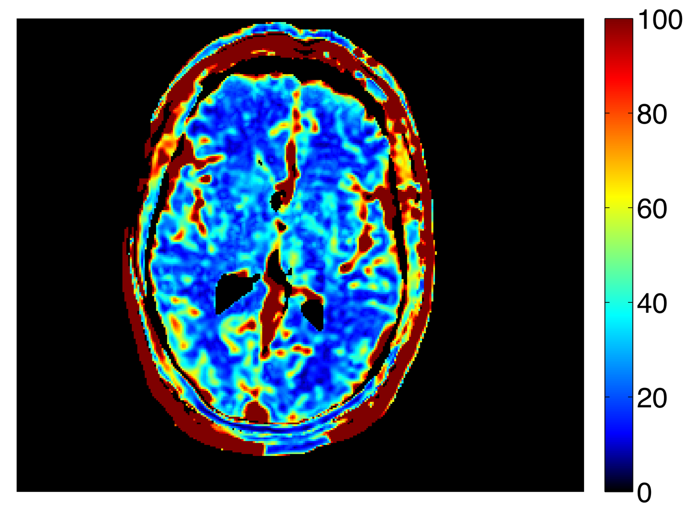

Fig 7: Example of the cerebral blood flow map of a healthy volunteer, derived from DCE MR using a TR of 9 ms, flip angle of 39° and BW of 6.41 kHz. Some anatomical differences within WM can be visually detected.

REFERENCES

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Lake Minnewanka, Alberta. Photo by JN Draper