# Enhanced Dynamic Contrast Enhanced (DCE) Magnetic Resonance (MR) for Brain Perfusion Imaging


Estee Lee,[1,3,4] M Ethan MacDonald,[1,3,4] and Richard Frayne [1-4]

[1]Biomedical Engineering, [2]Radiology and Clinical Neurosciences, [3]Hotchkiss Brain Institute, University of Calgary, Alberta, Canada
[4]Seaman Family MR Research Centre, Foothills Medical Centre, Alberta Health Services, Calgary, Alberta, Canada


## INTRODUCTION

- MR perfusion imaging provide clinically useful maps (CBF, CBV, MTT) for the identification of ischemic and infarcted brain tissue in stroke [1]
- In DCE MR imaging a linear relationship exists between signal intensity and (low ranges of) [contrast (Gd-DTPA)] [2]; accurate quantitative perfusion maps can be generated
- Objectives: To improve the precision of DCE MR brain perfusion imaging by 1) increasing signal change in brain tissue in the presence of a contrast agent ($\Delta S = S_{contrast} - S_{baseline}$), and 2) decreasing signal noise.

## HYPOTHESIS

To improve the precision of DCE perfusion measurements, the SPGR equation and the MR SNR-bandwidth (BW) relationship can be used to model signal in brain tissue, to select scanning parameters that maximize *ΔS* and/or minimize signal noise.

## PART I – INCREASING ΔS

- Modeling the SPGR equation [3]:

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

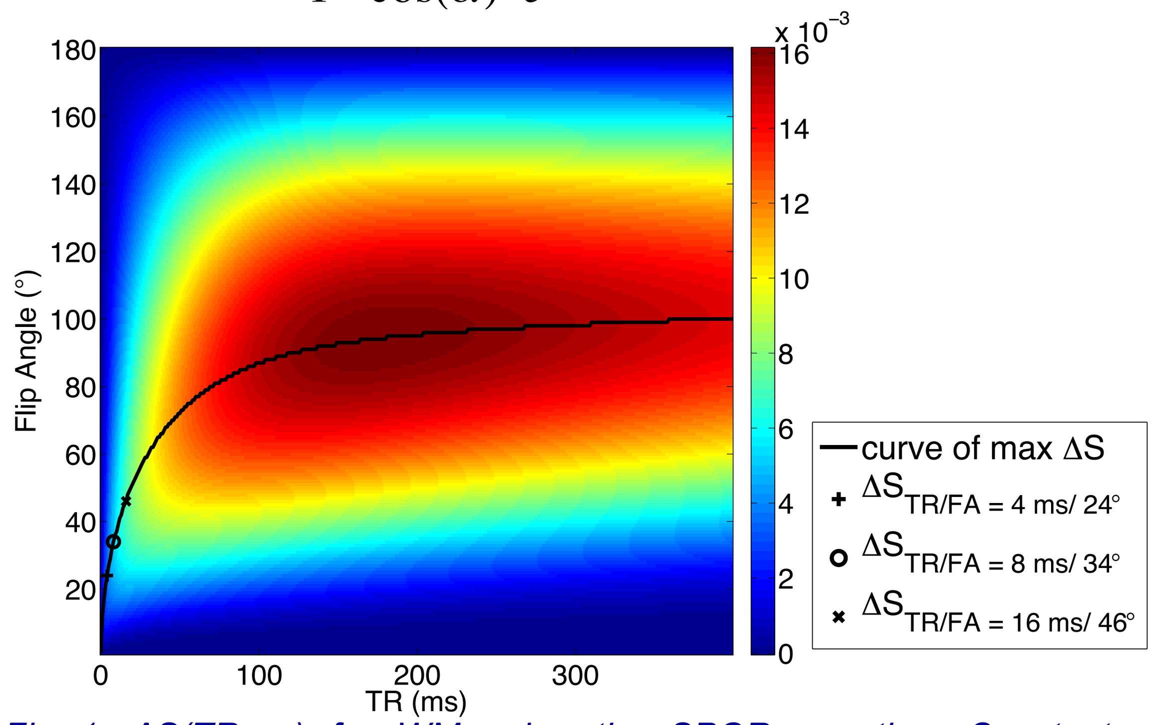


*Fig 1: ΔS(TR, α) for WM using the SPGR equation. Constant parameters: TE = 1.4 ms, $T_1$ = 1.1 s, $T_2^*$ = 70 ms, $r_1$ = 3.3 [Hz/mM], $r_2$ = 5.2 [Hz/mM], [Gd in arterial blood] = 8 mM. The maximum ΔS curve shows the optimal pairs of TR and α.*

### Phantom Experiment

*Fig 2: The phantom modeling brain tissue was made from dissolved agarose and Gd. Submerged PE and silicone tubing mimicked blood vessels. The phantom was scanned with saline and then with 8 mM Gd injected, at TR values of 4, 8, and 16 ms; other user-selected parameters were held constant.*

### Patient Experiment

- An acute stroke patient was scanned with DCE MR using TRICKS [4], with informed consent
- Scans were acquired at two TR (Fig 3) during the single injection for *ΔS* comparison

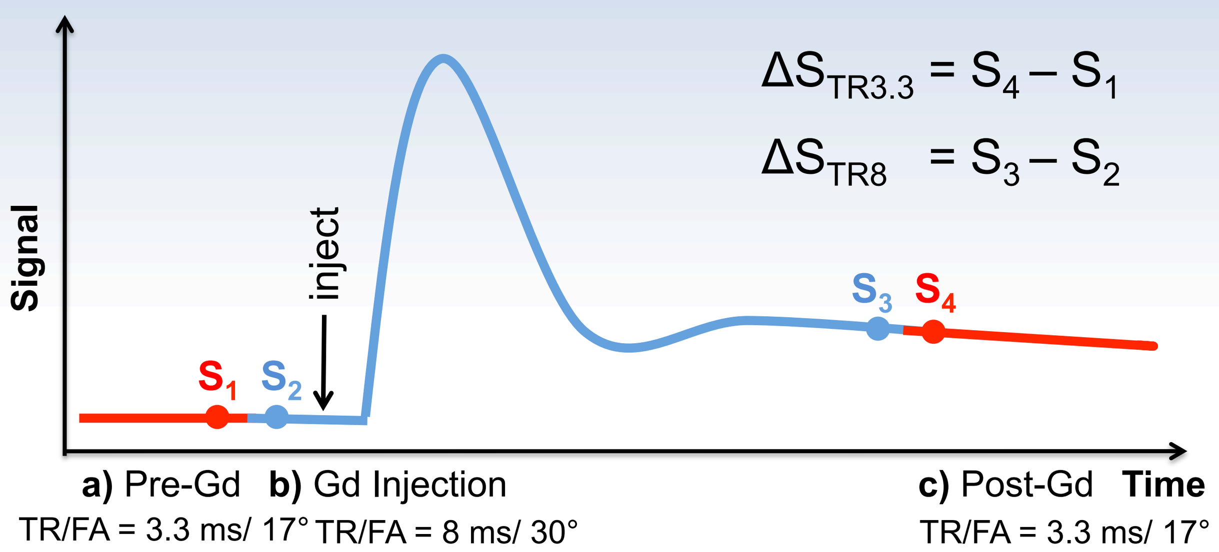


*Fig 3: The sequence of scans acquired pre- and post-Gd injection. ΔS is calculated by subtracting the baseline signal from the the post Gd signal (rather than peak signal) for direct comparison between $\Delta S_{TR3.3}$ and $\Delta S_{TR8}$. Assumption: there is no change in [Gd] between $S_1$ & $S_2$ and between $S_3$ & $S_4$.*

### Results

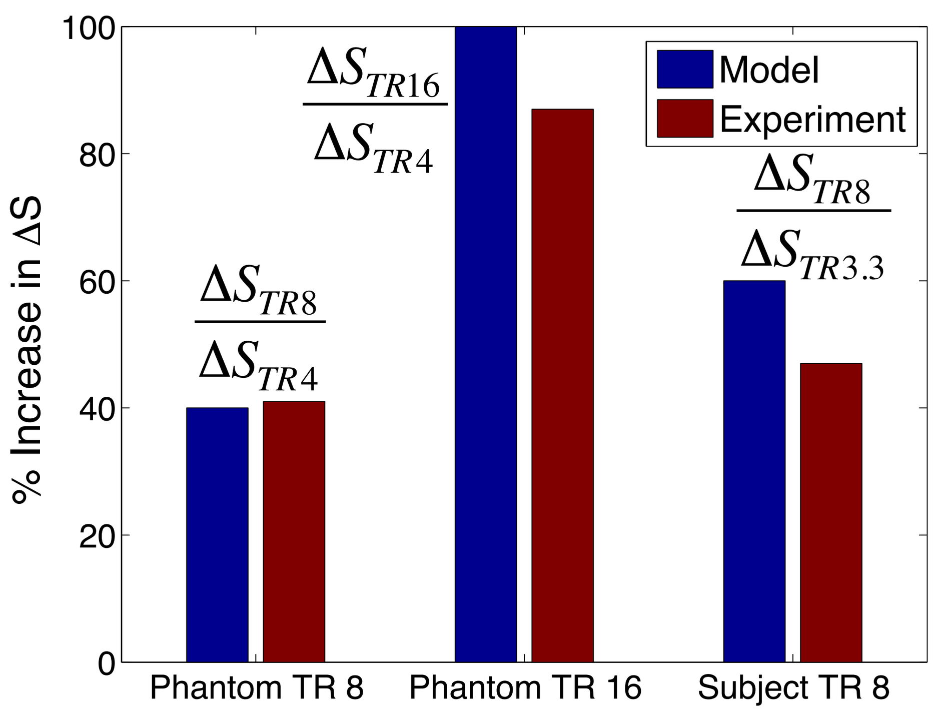


*Fig 4: Comparison of the percent increase in ΔS when longer TR is used compared to TR of 4 ms for phantom, and TR of 3.3 ms for patient. Model and experimental values are similar.*

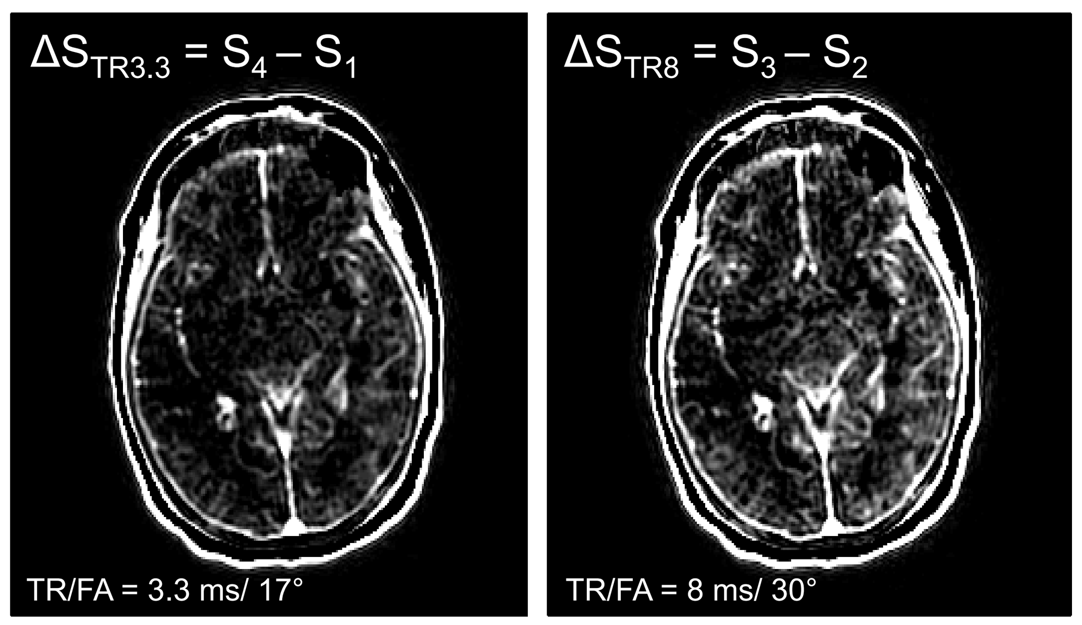


*Fig 5: ΔS of one slice of patient data, at the two sets of parameters scanned. Increased signal and physiological differences within WM and GM can be better visually observed at TR/FA of 8 ms/ 30°.*

### Discussion

- 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)
- Patient images visually and quantitatively showed increased signal difference in WM and GM regions using TR of 8 ms compared to TR of 3.3 ms (Fig 4 & 5)
- Selecting TR closer to the 'optimal range' as modeled (Fig 1) result in higher *ΔS* with contrast agent injected

## PART II – DECREASING NOISE

- The relation $SNR \propto 1/\sqrt{BW}$ [5] was tested
- A spherical phantom containing dimethyl silicone fluid, Gd, and colorant was scanned at a range of BW
- The SPGR sequence was used to scan the phantom at three sets of TR/BW: 8 ms/25 kHz, 16 ms/25 kHz, and 16 ms/ 6.41 kHz
- Lower BW required longer readout time

### Results

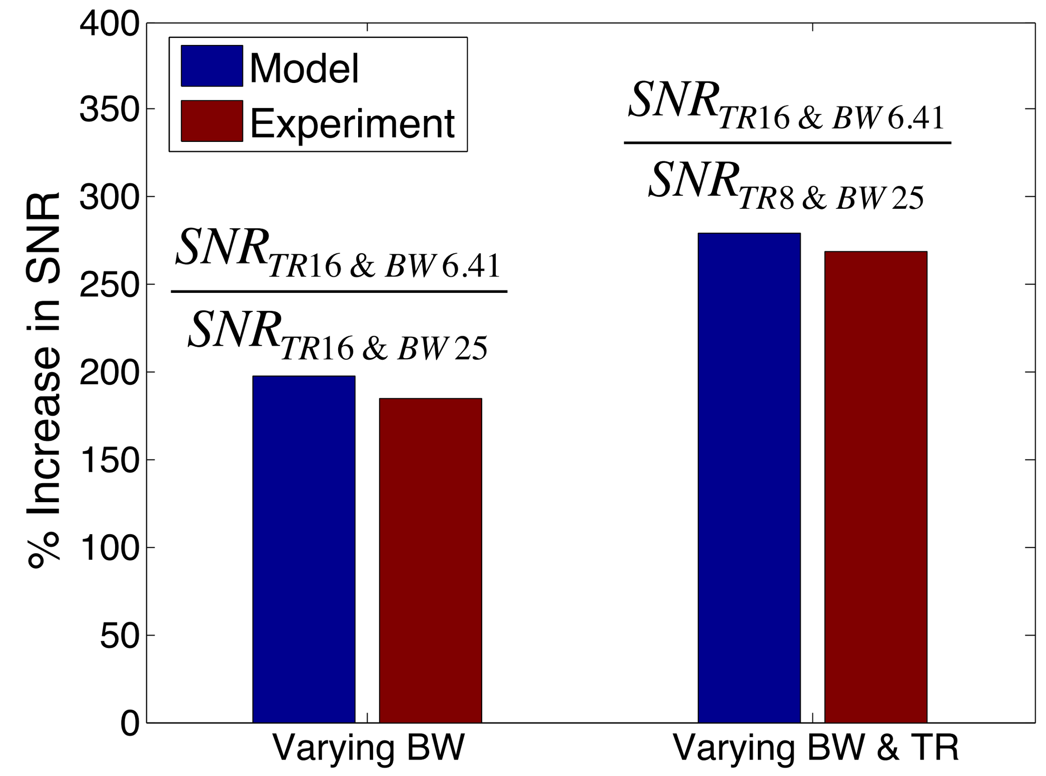


*Fig 6: Percent increase in SNR by varying BW and/or TR, calculated from mid-volume circular ROI. 24 time phases were scanned at a TR of 8 ms and 12 time phases were scanned at a TR of 16 ms.*

### Discussion

- Lowering BW and increasing TR resulted in the theorized increases in measured SNR
- The longest TR and lowest BW combination resulted in the highest SNR increase
- This suggests that longer TR (closer to 'optimal') and lower BW are needed to improve perfusion measurements

## CONCLUSIONS

- Modeling WM with the SPGR equation allowed selection of more optimal TR and flip angle values to increase *ΔS* in both phantom and patient experiments
- Analytical analysis and phantom validation demonstrated that decreasing BW increased SNR
- Selecting an appropriate combination of scanning parameters can improve DCE MR perfusion measurements to better observe strokes anatomically and hemodynamically (Fig. 7)

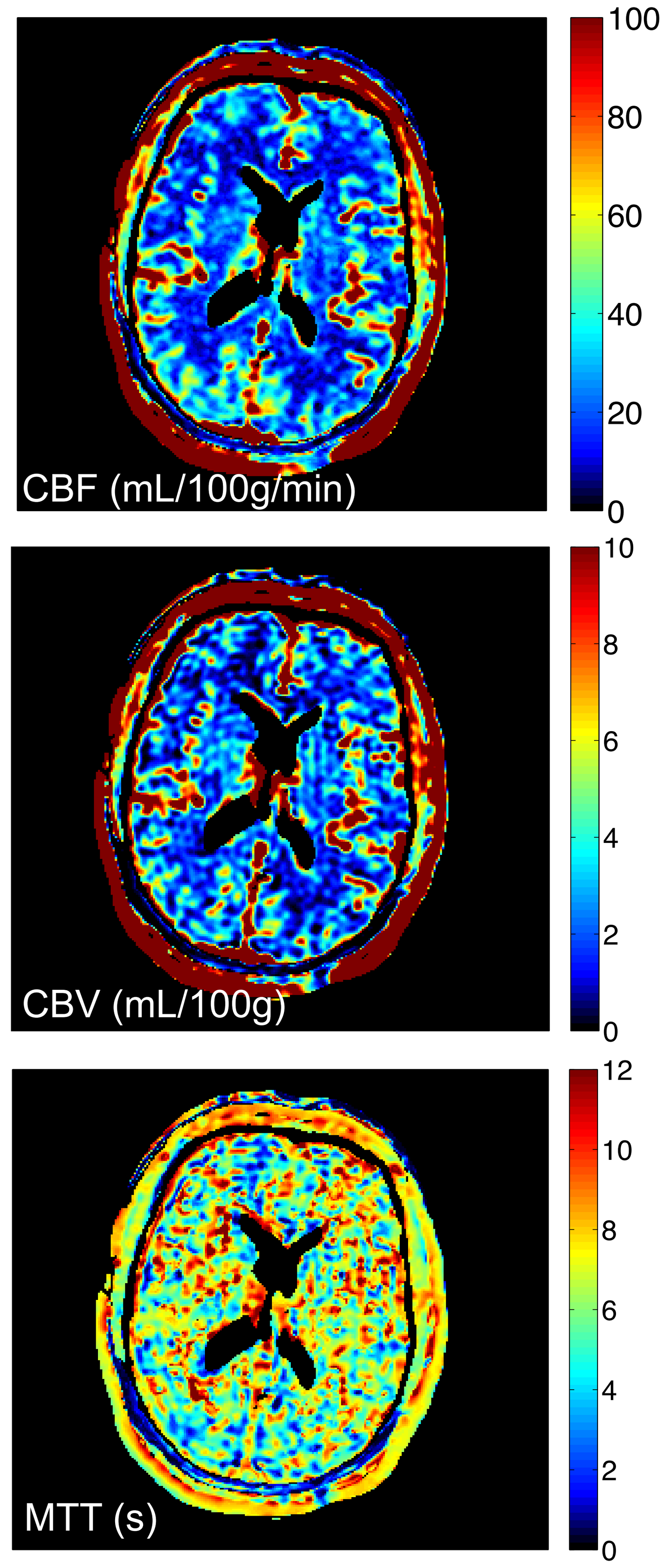


*Fig 7: Example of preliminary CBF, CBV, and MTT maps of a healthy volunteer, derived from DCE MR using a TR of 9 ms, flip angle of 39° and BW of 6.41 kHz. Some anatomical differences within WM can be seen.*

## REFERENCES


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www.MRcentre.ca
eslee@ucalgary.ca


Lake Minnewanka, Alberta. Photo by JN Draper