Characterizing the voxel-wise Contrast to Noise Ratio of the Consensus Single-Dose Low Flip Angle DSC-MRI Perfusion Imaging Protocol

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ABSTRACT

Purpose:
Single-dose LFA DSC-MRI is the consensus protocol for brain tumor perfusion imaging, but reduced flip angles may compromise voxel-wise CNR and clinical interpretability. This study evaluates whether LFA DSC-MRI preserves diagnostic-quality CNR for CBV mapping across scanners and field strengths while reducing gadolinium dose.

Methods:
54 glioblastoma patients (Barrow) underwent sequential single-dose LFA and double-dose MFA DSC-MRI on a 3T scanner. 10 additional patients (MD Anderson) were scanned with LFA across 1.5T and 3T systems. Tumor ROIs were transferred to coregistered DSC data, voxel-wise ΔR2* computed with leakage correction, and CNR calculated as peak ΔR2* divided by baseline standard deviation. Voxels meeting CNR ≥ 4 were quantified.

Results:
At 3T, LFA and MFA both achieved CNR ≥ 4 in more than 86% of tumor voxels. At 1.5T, LFA CNR trended lower, with 20–30% fewer voxels meeting the reliability threshold compared to 3T.

Conclusion:
Single-dose LFA DSC-MRI maintains comparable voxel-wise CNR to double-dose MFA at 3T while reducing gadolinium exposure by 50%. Performance trends lower at 1.5T, warranting further comparison with MFA at that field strength. Clinical impact will require validation in a radiology reader study.

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INTRODUCTION

Glioblastoma (GBM) is the most aggressive primary brain tumor, and imaging plays a central role in guiding treatment decisions. DSC-MRI-based cerebral blood volume (CBV) mapping is widely used to assess tumor vascularity and monitor treatment response. The 2020 consensus protocol recommends two acquisition options: double-dose moderate flip angle (MFA, 60°) and single-dose low flip angle (LFA, 30°).

While ROI-level CBV values show strong agreement between protocols, reliable CBV mapping requires a voxel-wise CNR ≥ 4. A lower flip angle inherently reduces signal, and the impact of the LFA protocol on voxel-wise CNR — which directly affects the CBV maps used for radiologic evaluation — has not been systematically evaluated.

METHODS

Two cohorts of glioblastoma patients were studied. Cohort 1 (Barrow, n=54) underwent sequential single-dose LFA and double-dose MFA DSC-MRI on a 3T scanner for protocol comparison. Cohort 2 (MD Anderson, n=10) was scanned with the LFA protocol across 1.5T and 3T systems to assess generalizability.

DICOMs were converted to NIfTI and DSC-MRI images were motion corrected and registered to post-contrast T1w images. BraTS tumor labels were converted to binary ROI masks, and GM/WM masks were generated using FSL FAST. All ROIs were registered to DSC space for voxel-wise analysis. ΔR2* time series were computed per voxel, and CNR was calculated as peak ΔR2* divided by the baseline standard deviation (σ_BL). Voxels meeting CNR ≥ 4 were quantified and compared between protocols.

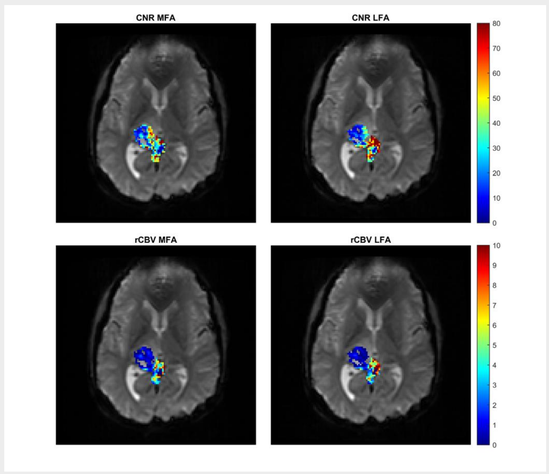

Figure 1. Voxel-wise CNR (top) and rCBV (bottom) maps comparing moderate-flip-angle (*MFA*, left) and low-flip-angle (*LFA*, right) DSC-MRI in recurrent glioblastoma. Both protocols demonstrate similar spatial distributions of high CNR and elevated rCBV within the enhancing tumor region, indicating strong quantitative agreement (CCC= 0.952).

RESULTS

At 3T, LFA and MFA demonstrated similar voxel-wise CNR distributions in enhancing tumor (mean CNR: 57.9 vs 65.8), with both protocols achieving CNR ≥ 4 in more than 86% of tumor voxels (LFA 86.1 ± 15.3% vs MFA 86.0 ± 15.9%, p = 0.95).

No statistically significant differences were observed in GM (LFA 91.9 ± 9.4% vs MFA 90.9 ± 11.9%, p = 0.12) or WM (LFA 95.2 ± 6.8% vs MFA 94.2 ± 12.0%, p = 0.27).

Spatial distributions of CNR and rCBV were visually comparable between protocols, with strong quantitative agreement (CCC = 0.952).

At 1.5T, LFA CNR trended lower (mean CNR: 15.8 vs 42.4 at 3T), with 20–30% fewer voxels meeting the CNR ≥ 4 reliability threshold compared to 3T.

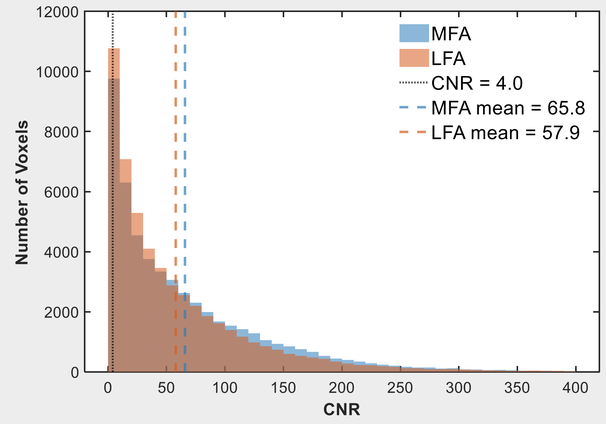

Figure 2. Voxel-wise CNR distributions for MFA and LFA in enhancing tumor voxels at 3T. Both distributions are right-skewed with means well above the CNR ≥ 4 reliability threshold and show substantial overlap despite a modest reduction in LFA mean CNR (57.9 vs 65.8).

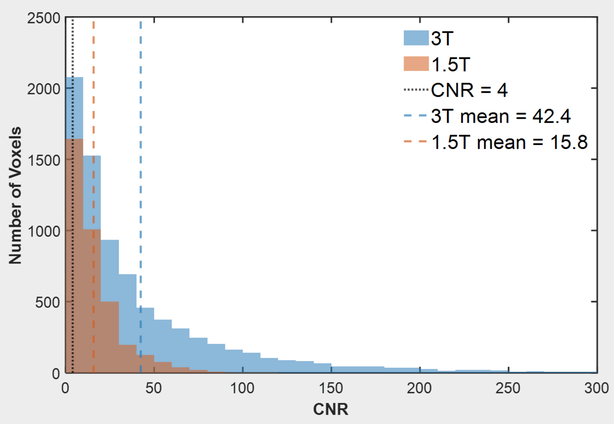

Figure 3. Voxel-wise CNR distributions for LFA DSC-MRI at 1.5T vs 3T in enhancing tumor voxels. The 1.5T distribution shifts leftward (mean CNR: 15.8 vs 42.4).

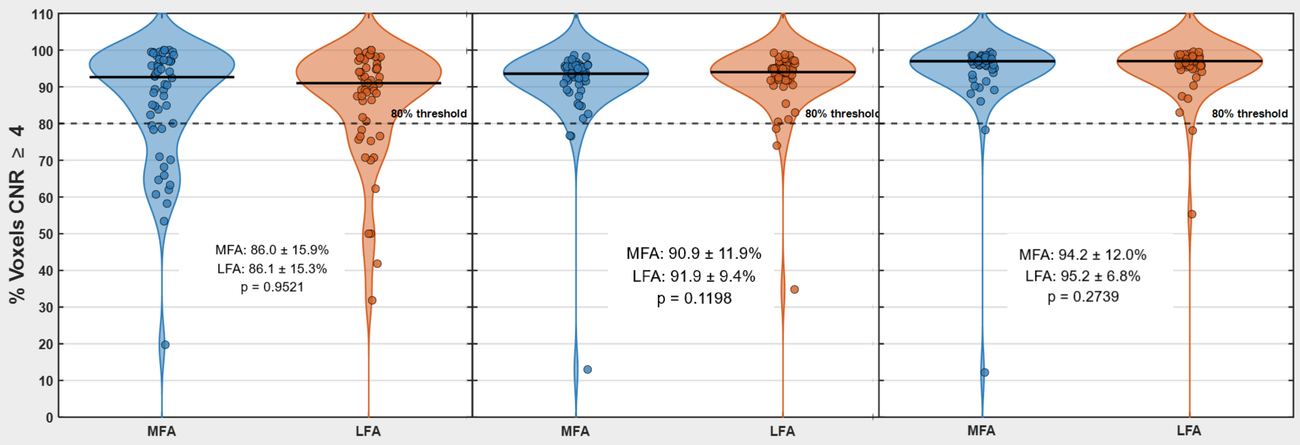

Figure 4. Percent of voxels meeting CNR ≥ 4 for MFA and LFA across tumor, GM, and WM at 3T. No statistically significant differences were observed in any tissue compartment, with both protocols exceeding 86% coverage in tumor voxels.

DISCUSSION & CONCLUSIONS

- Single-dose LFA DSC-MRI preserves diagnostic-quality voxel-wise CNR for CBV mapping compared to double-dose MFA at 3T, with no statistically significant difference across tumor, GM, or WM.
- Strong spatial and quantitative agreement in rCBV maps (CCC = 0.952) supports the clinical use of the consensus LFA protocol at 3T while reducing gadolinium dose by 50%.
- LFA CNR trends lower at 1.5T, with 20–30% fewer voxels meeting the reliability threshold compared to 3T, warranting further investigation including MFA comparison at 1.5T.
- Future work should assess the clinical impact of CNR differences through a radiology reader study.

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