Quantitative BOLD modeling of brain oxygenation during vasodilation

ISMRM-Endorsed Workshop – Quantitative Imaging

Linh Le

UC Davis

Oxygen Extraction Fraction

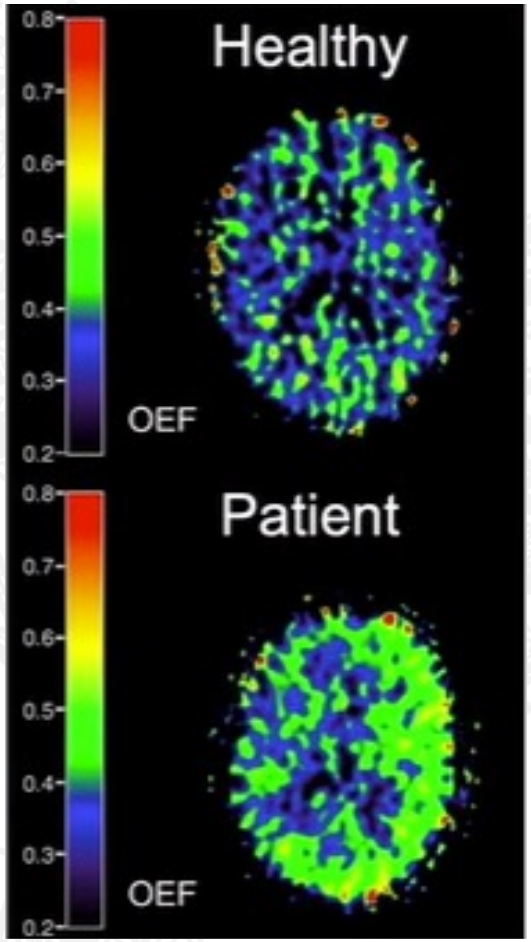
OEF is a measurement of oxygen consumed by metabolism

- Function of perfusion and oxygen metabolism
- Can be combined with perfusion to measure oxygen metabolism
- Arterial-venous difference in blood oxygen saturation

OEF is dimensionless

- Healthy resting brain range: 0.3-0.4

^{15}O PET OEF measurements



Bremmer JP, et al. Mol. Imaging Biol. 2011; 13:759-768

Oxygen Extraction Fraction

OEF consumption in brain

- Altered during disease/activity

Current benchmark

- Triple oxygen PET
- Highly specialized, invasive, expensive and difficult to perform

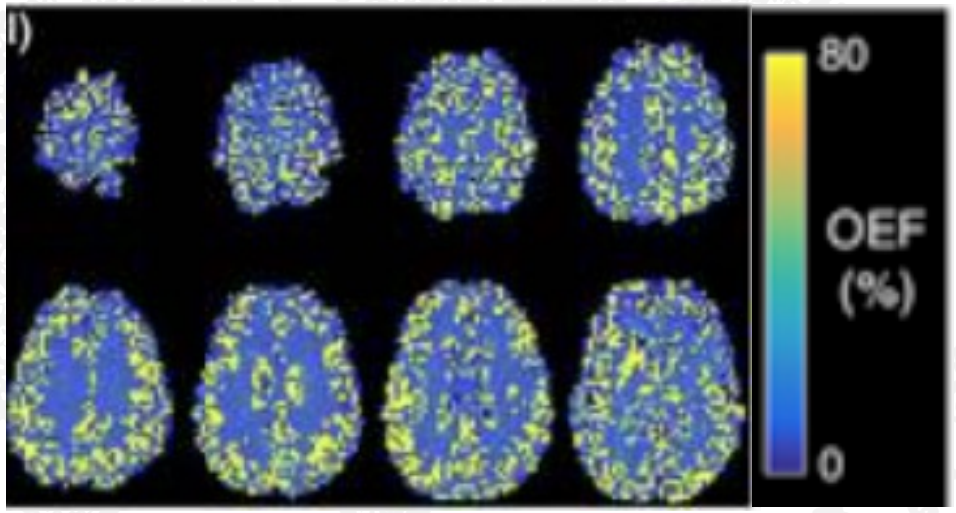
Alternative quantitative technique

- Clinical applicable

Quantitative BOLD (qBOLD)

Quantitative BOLD

- Models MR signal decay in microvessels
- qBOLD signal is influenced by concentration of deoxyhemoglobin, which is relatively sensitive to OEF
- Quantified through the reversible transverse relaxation rate R2’



Cherukara et al., Neuroimage 2019; 202: 116106

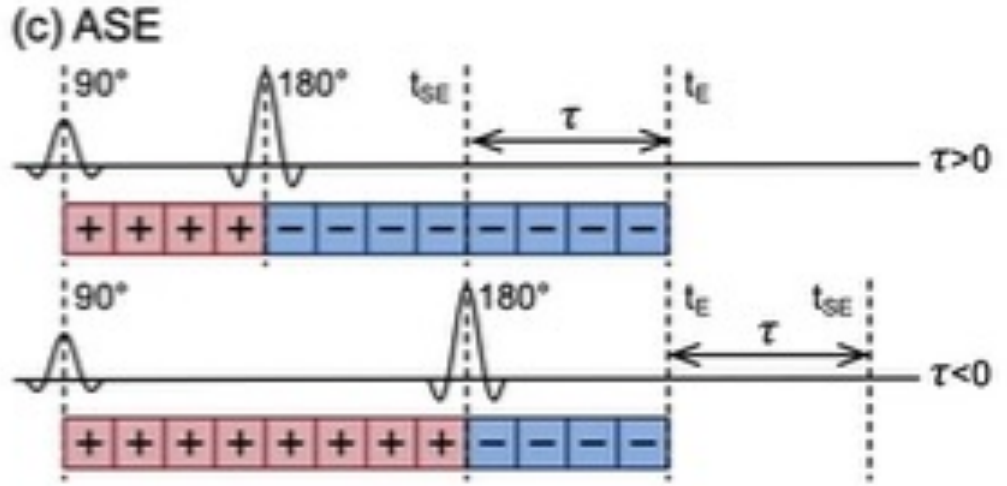
Methods

ASE data: Asymmetric Spin Echo

- Acquires only a single TE
- Refocusing pulse is moved

Participants

- 3 healthy controls
- Received ASE before and after acetazolamide (dose of 15mg/kg) (i.e. vasodilator)



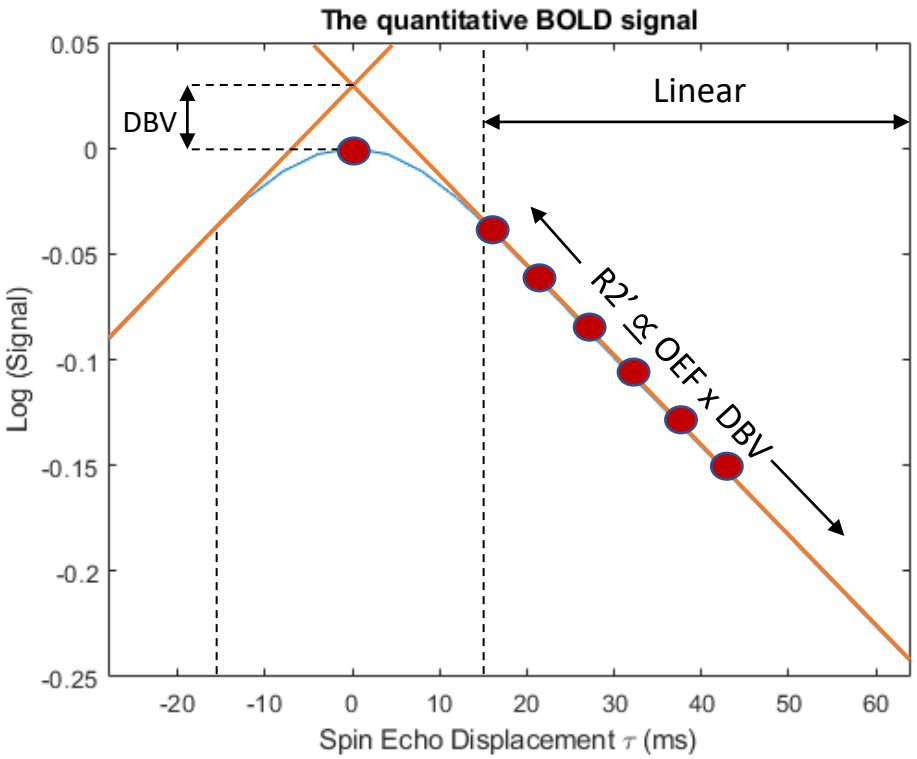
How do we quantify OEF?

1. **Acquire R2'-weighted data**
   - Asymmetric Spin Echo
   - Achieve gradient echo sampling of spin echo

2. **Estimate R2' from long tau data**
   - Log-linear fit to tau>15ms data
   - R2' $\propto$ OEF x DBV

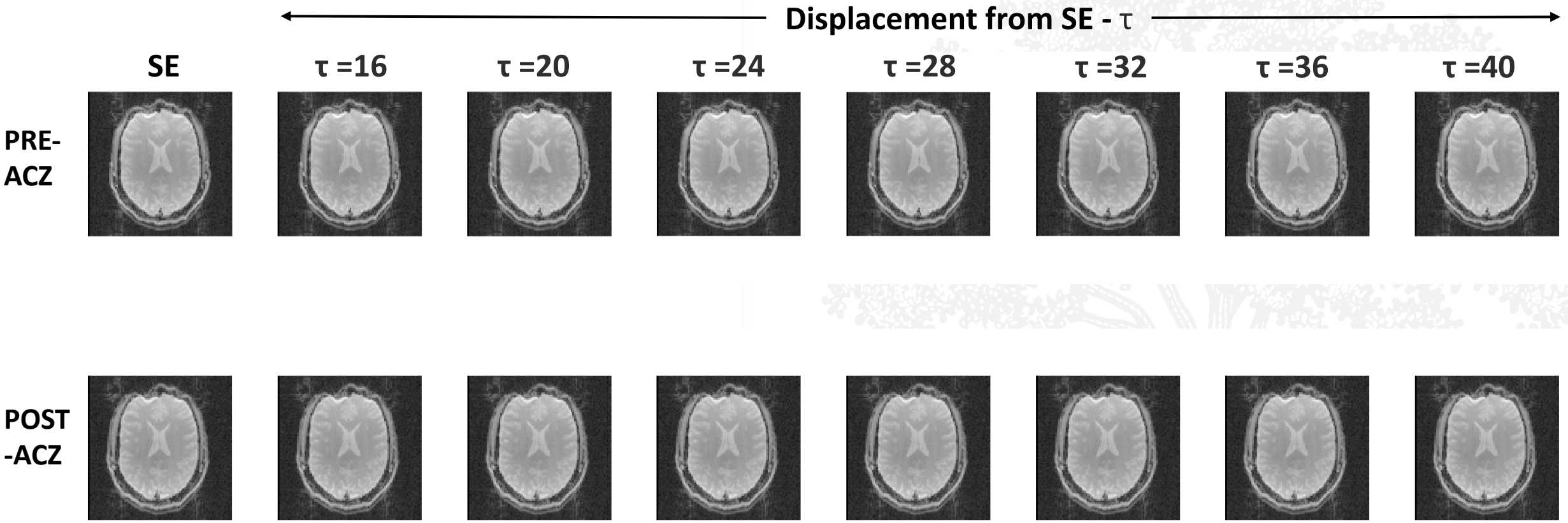
3. **Estimate DBV from spin echo**
   - Difference between intercept and measured SE signal

4. **Estimate OEF from R2' and DBV**
   - Known constants of proportionality used to quantify OEF

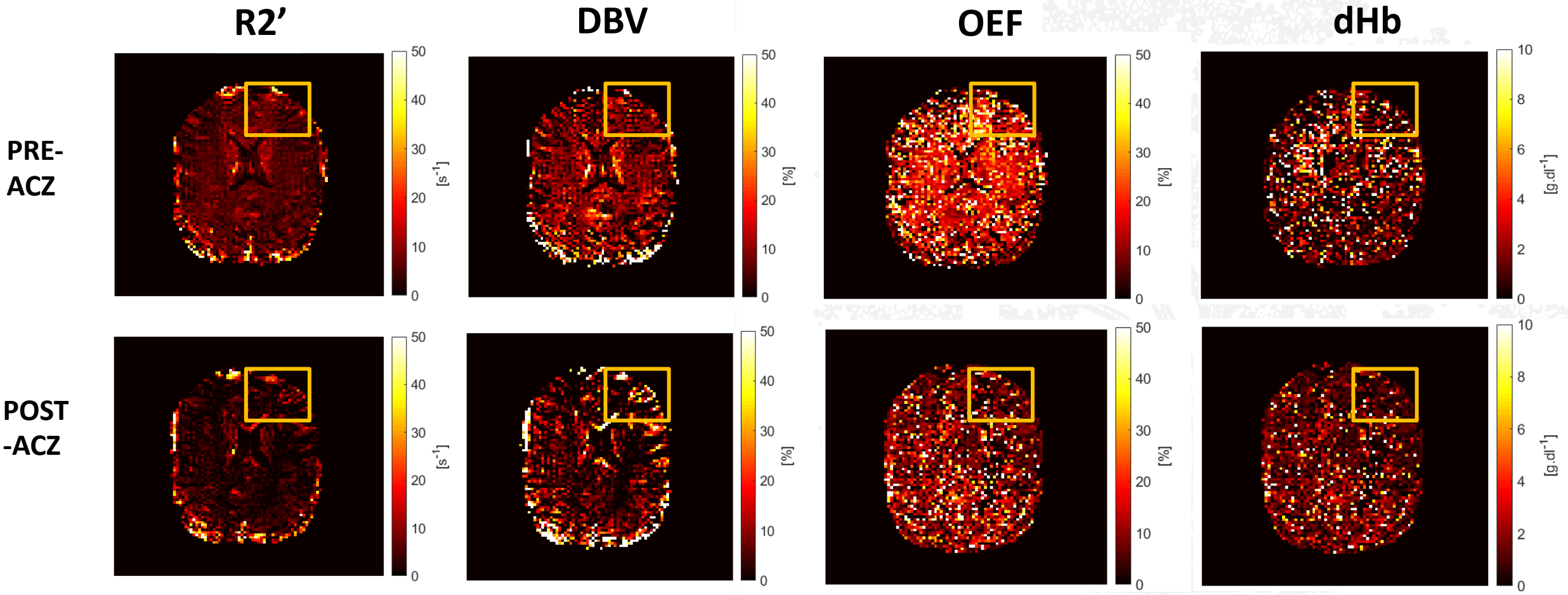


Stone and Blockley, NeuroImage (2017); 147:79-88

ASE Images during vasodilation



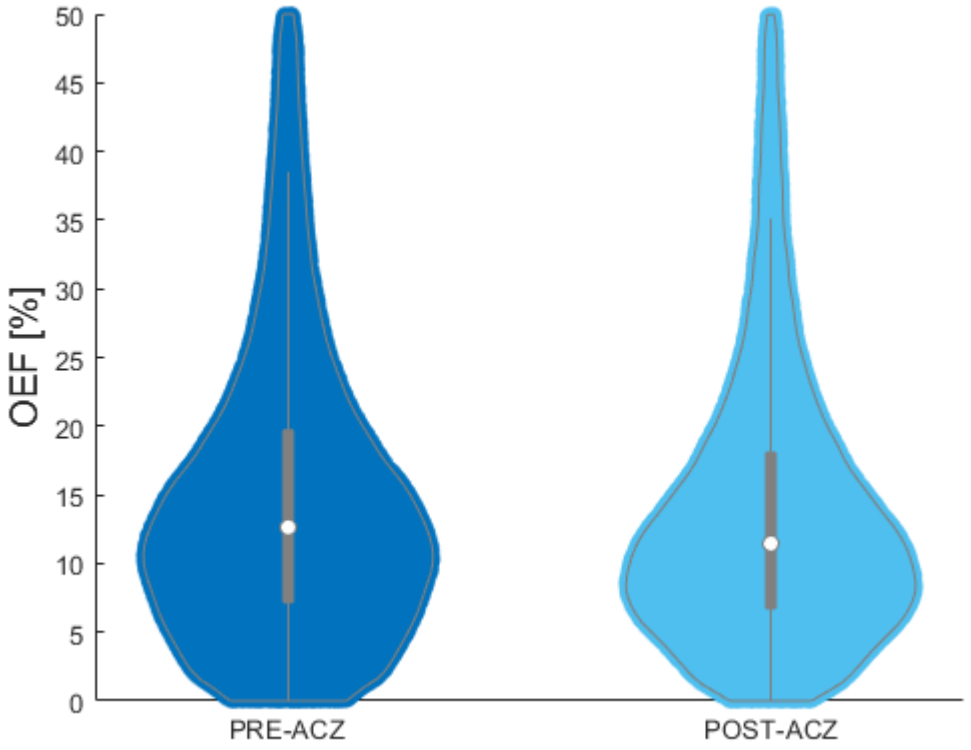
Results - OEF decreased during vasodilation



Results – Whole brain analysis

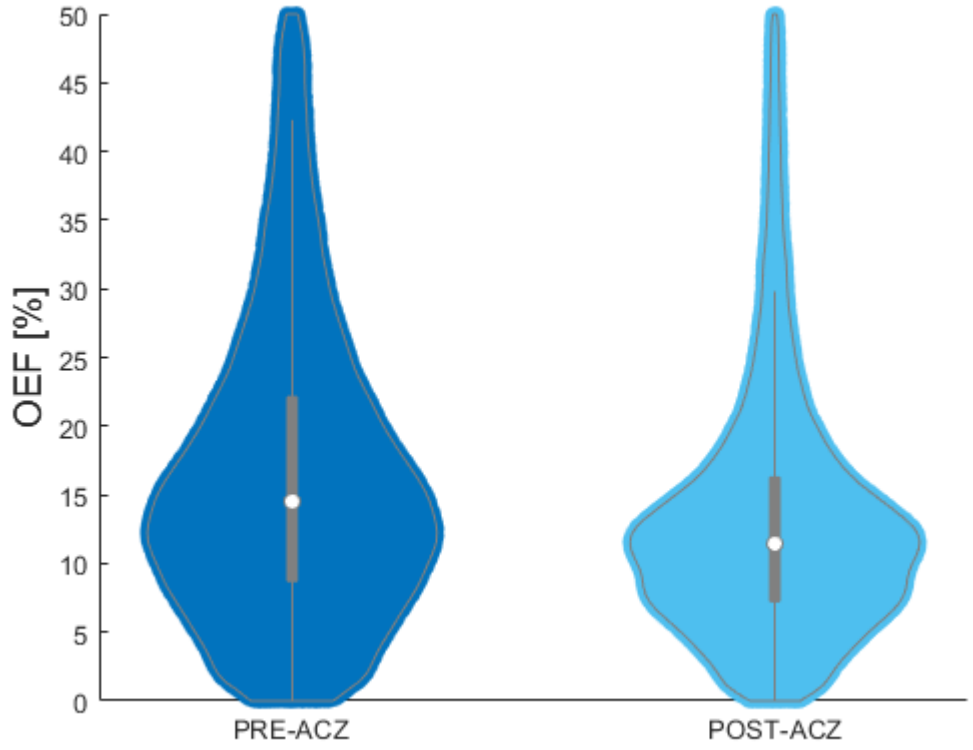
Subject #1

%OEF change = **9.4%**



Subject #2

%OEF change = **21.2%**



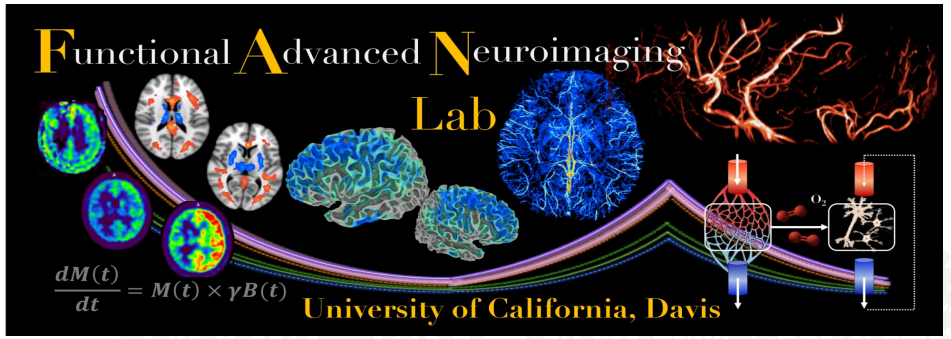
Conclusion

- qBOLD is efficient in computational time, non-invasive
- There was a downward trend of OEF with increasing acetazolamide response

Future steps:

- Linear model is noisy
  - Consider Bayesian framework

Acknowledgement



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