

Echo-planar Imaging distortion correction in Glioblastoma patients

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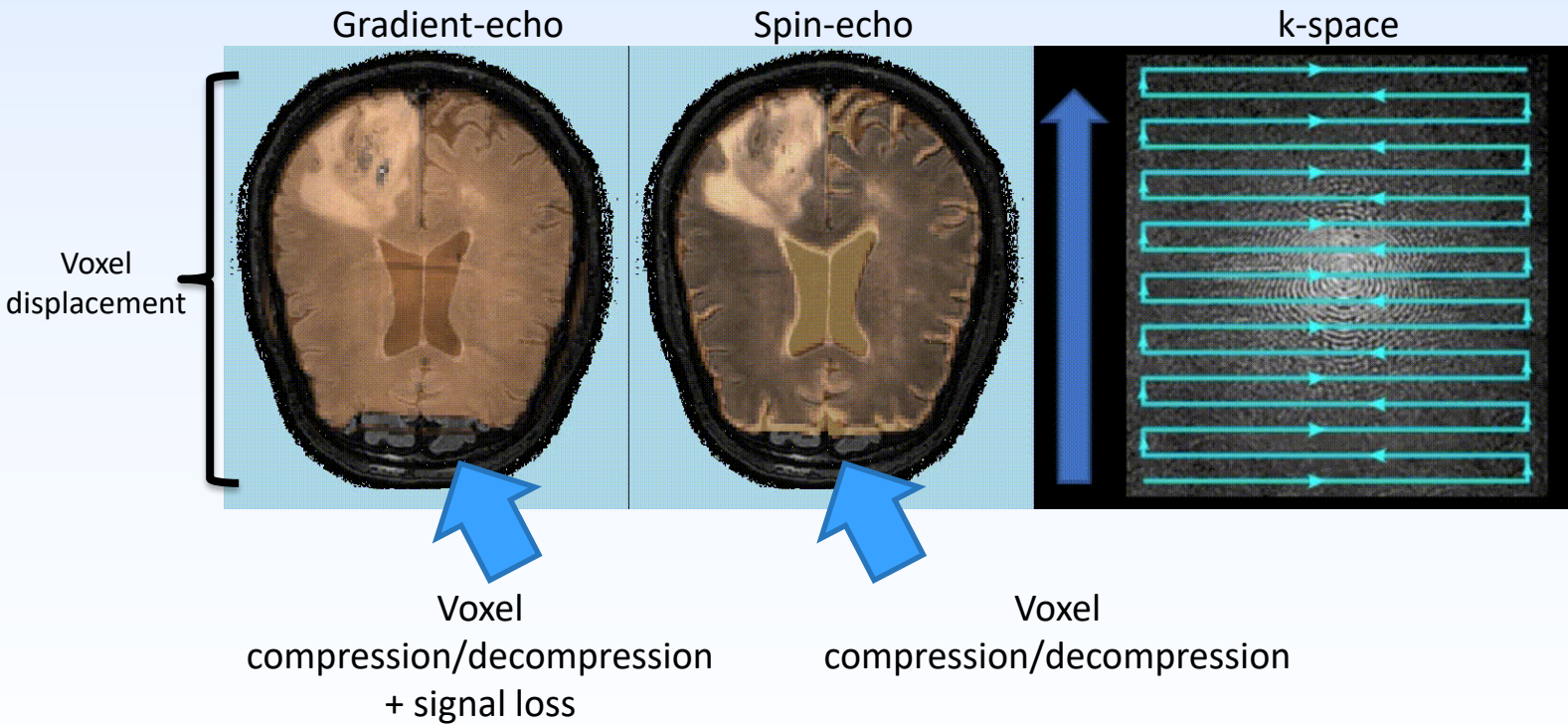
MRI in Clinical Cancer Therapy

Diagnostic Physics

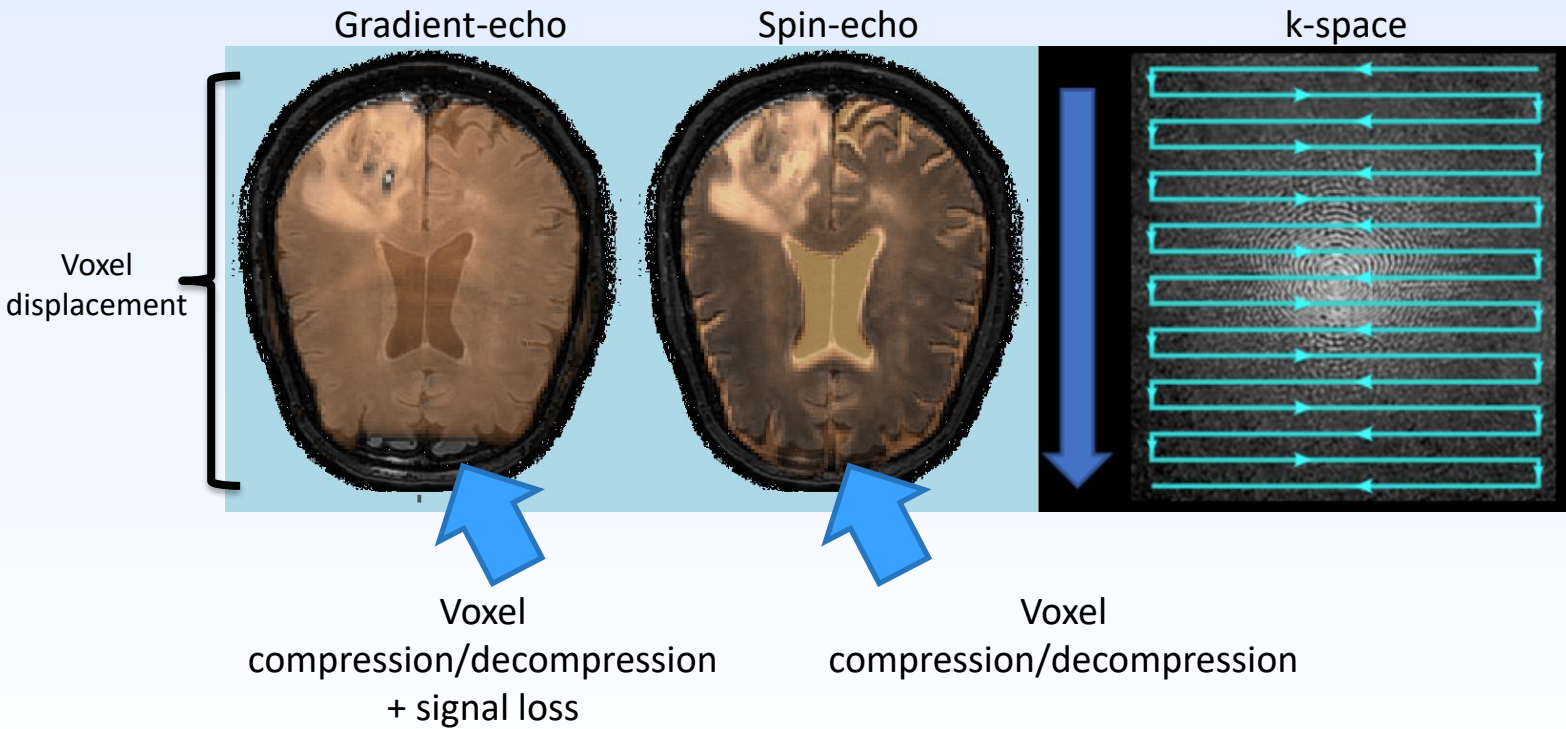
Outline

1. Why EPI distortion correction?
2. Relevance in the ImPRESS study
3. Impact on Relative Cerebral Blood Volume (rCBV)

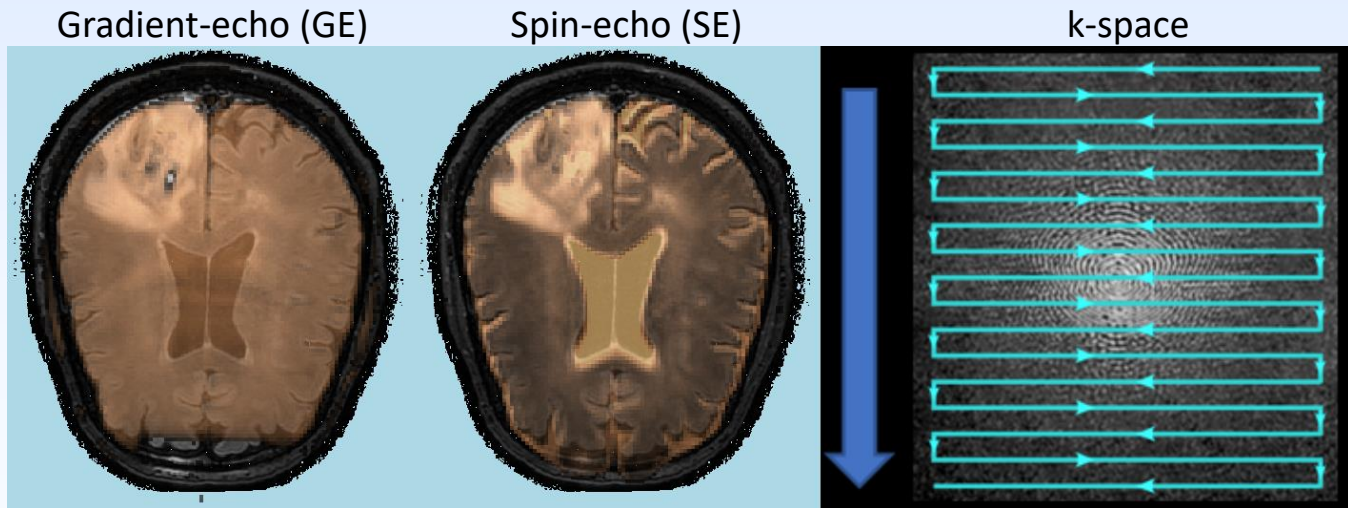
1. EPI susceptibility distortions example



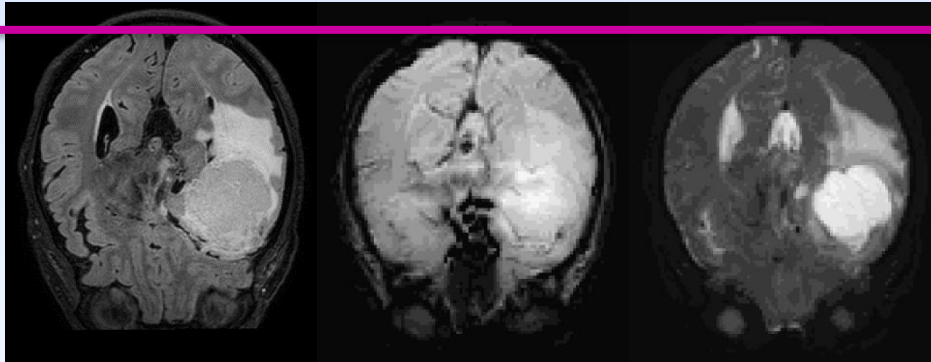
1. EPI susceptibility distortions example



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$\times 100 = \text{Dynamic Susceptibility Contrast (DSC)}$



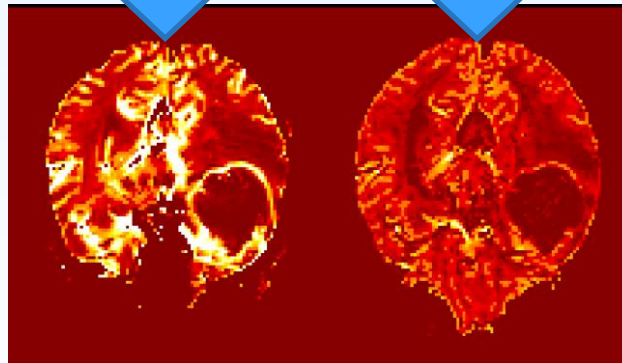
T2 FLAIR

GE DSC (T2*)

SE DSC (T2)

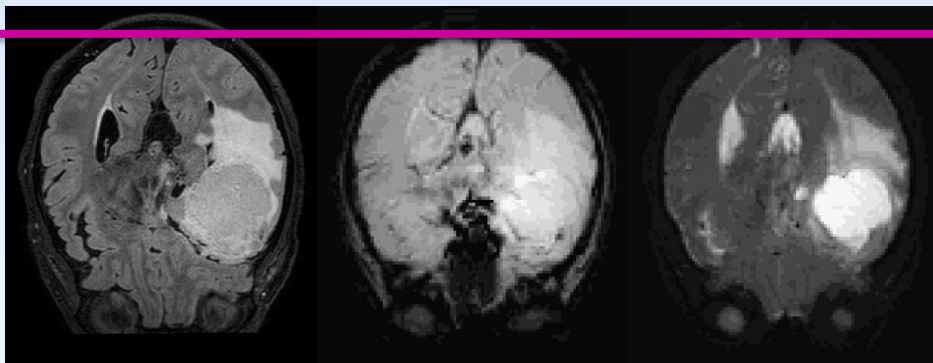
Uncorrected
DSC

rCBV



$$\Delta R2^* = -\frac{1}{TE} \ln\left(\frac{S(t)}{S_0}\right)$$

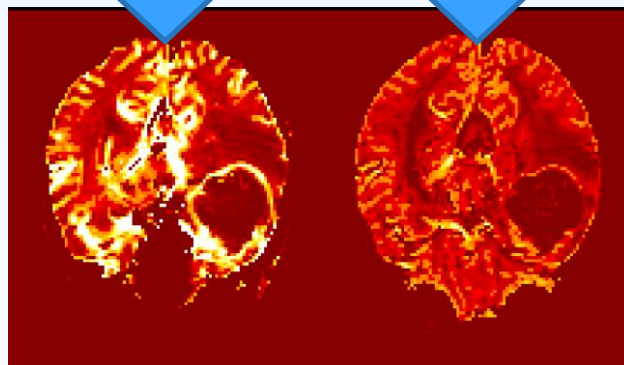
$$rCBV \propto \int \Delta R2^* dt$$



T2 FLAIR

GE DSC (T2*)

SE DSC (T2)



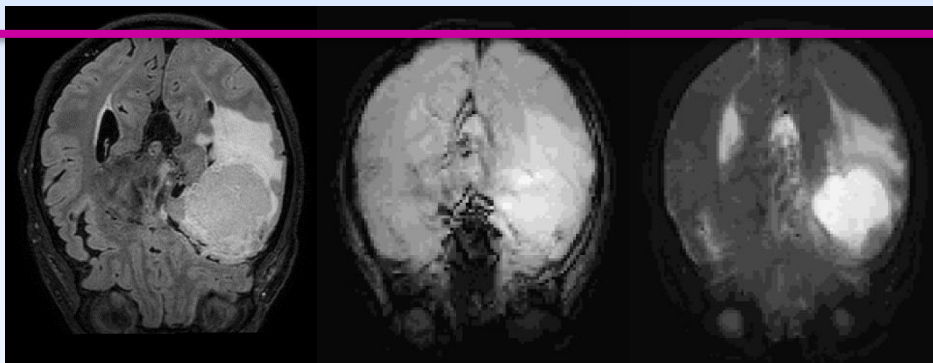
rCBV

Corrected DSC (FSL TOPUP)

Andersson et al.
2003

$$\Delta R2^* = -\frac{1}{TE} \ln\left(\frac{S(t)}{S_0}\right)$$

$$rCBV \propto \int \Delta R2^* dt$$



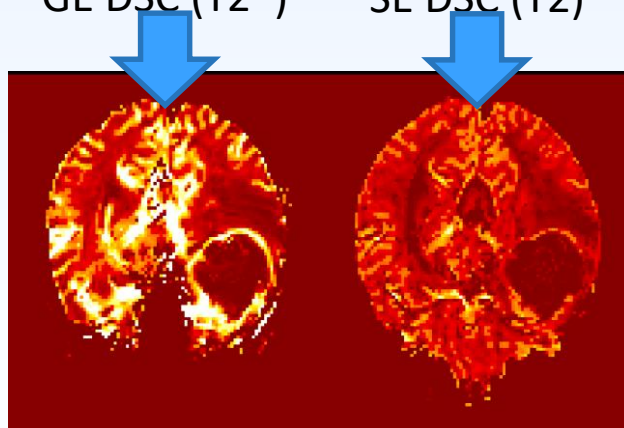
T2 FLAIR

GE DSC (T2*)

SE DSC (T2)

Corrected DSC (EPIC)

Holland et al. 2010



rCBV

$$\Delta R2^* = -\frac{1}{TE} \ln\left(\frac{S(t)}{S_0}\right)$$

$$rCBV \propto \int \Delta R2^* dt$$

ImPRESS Study (2018-2022)

- Imaging Perfusion Restrictions from Extracellular Solid Stress
- Cancer can affect the biomechanical properties of tissue¹⁻³

¹ Kumar et al. Cancer Metastasis Rev. 2009

² Jain et al. Annu. Rev. Biomed Eng. 2014

³ Stylianopoulos et al. Trends Cancer 2018

- Hypothesis: Solid stress restricts the tumor perfusion microenvironment and thus promotes therapy resistance

Treatment:

Chemotherapy, radiotherapy, surgery + *losartan*

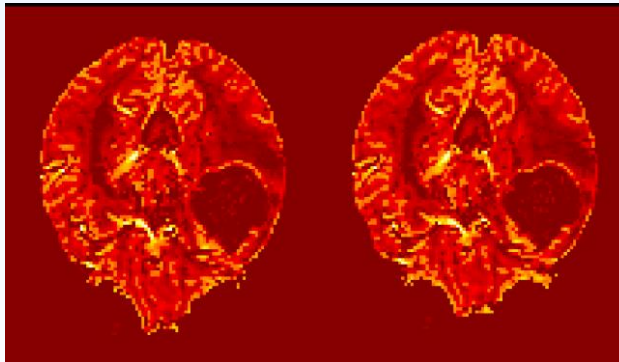
ImPRESS Study (2018-2022): PhD

- We need accurate in-vivo measurement of treatment response
- Objective 1: Accurate co-registration of perfusion and structural images (this work)
- Objective 2: Voxel tracking during treatment (longitudinal)
- Outcome: Enable analysis of biomechanical changes (stiffness, vascularity) during treatment which can improve MRI-based description and prediction of treatment outcome (f. ex. tumor progression vs. pseudoprogression)

Objective 1: Accurate co-registration of perfusion and structural images

- EPI distortion correction: FSL TOPUP and EPIC
- How does EPI distortion correction impact rCBV?

Before



After

How does EPI distortion correction impact rCBV? – Method

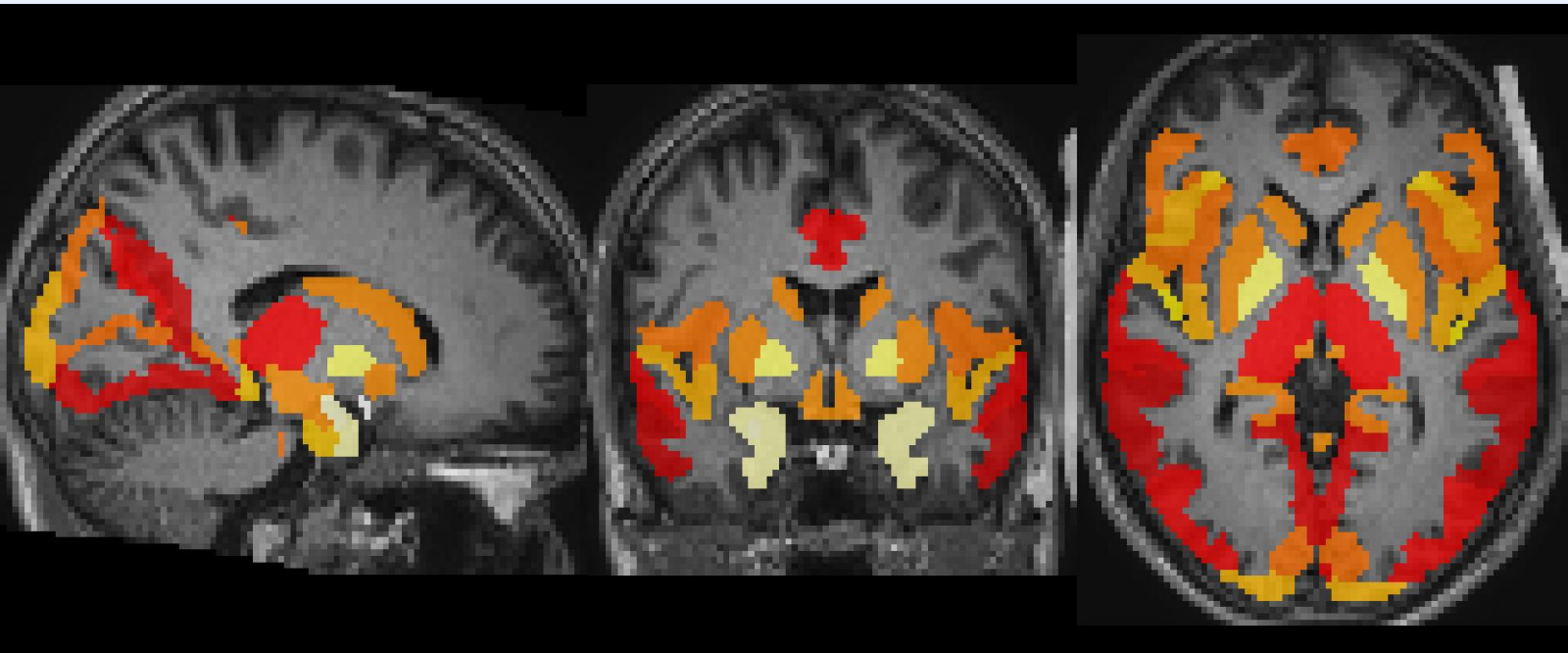
- 45 patients, aged 40-84 (median 61)
- Baseline, pre-treatment scans: DSC + 3D T2-FLAIR
- Head motion correction, EPI distortion correction, MNI normalization (2x2x2mm)
- Region inclusion criteria:
 - Non-tumor (necrotic, enhancing & edema)
 - Not ventricles and cerebrospinal fluid (CSF)
 - Minimum 30 voxels
 - Minimum 70 % overlap with rCBV axial slices
 - Minimum 10 patients for each region comparison

How does EPI distortion correction impact rCBV? – Method

- Look for changes in histograms in 66 brain regions using:
 1. Hellinger distance
 2. Wasserstein distance
 3. Wilcoxon signed-rank test for significant rCBV change w. Bonferroni correction ($p < 0.05 / (\text{num. test regions})$)

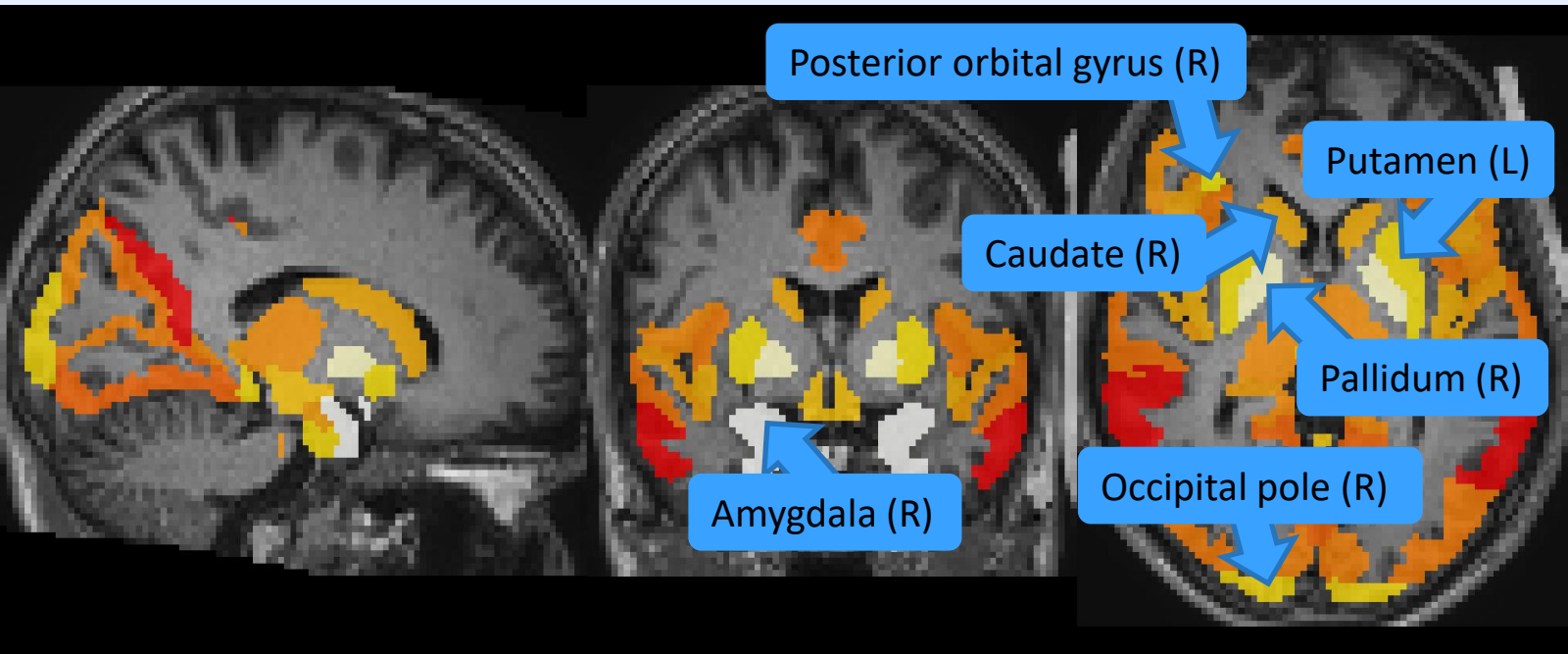
How does EPI distortion correction impact rCBV?

1. Overall Hellinger distances (means of medians)



How does EPI distortion correction impact rCBV?

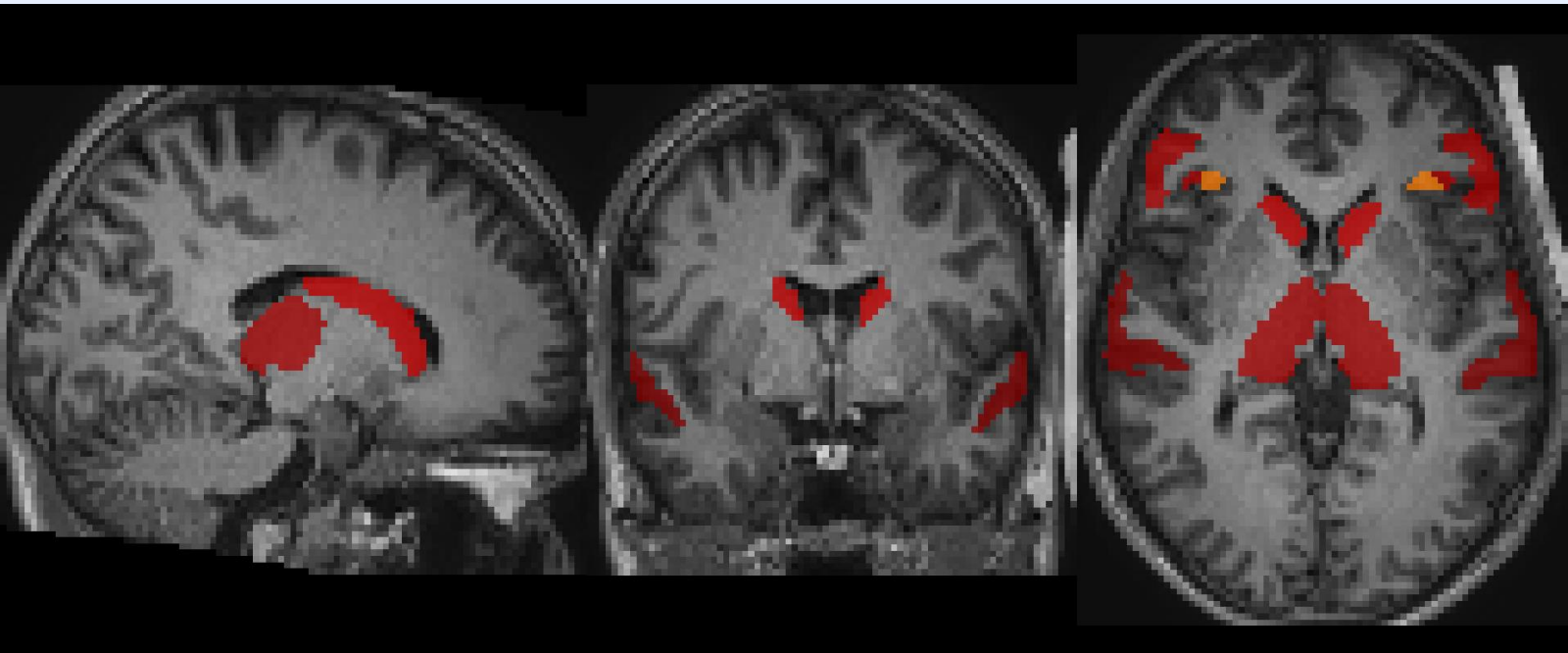
2. Overall Wasserstein distances (means of medians)



How much does EPI distortion correction impact rCBV?

Significant rCBV increase
TOPUP Gradient Echo

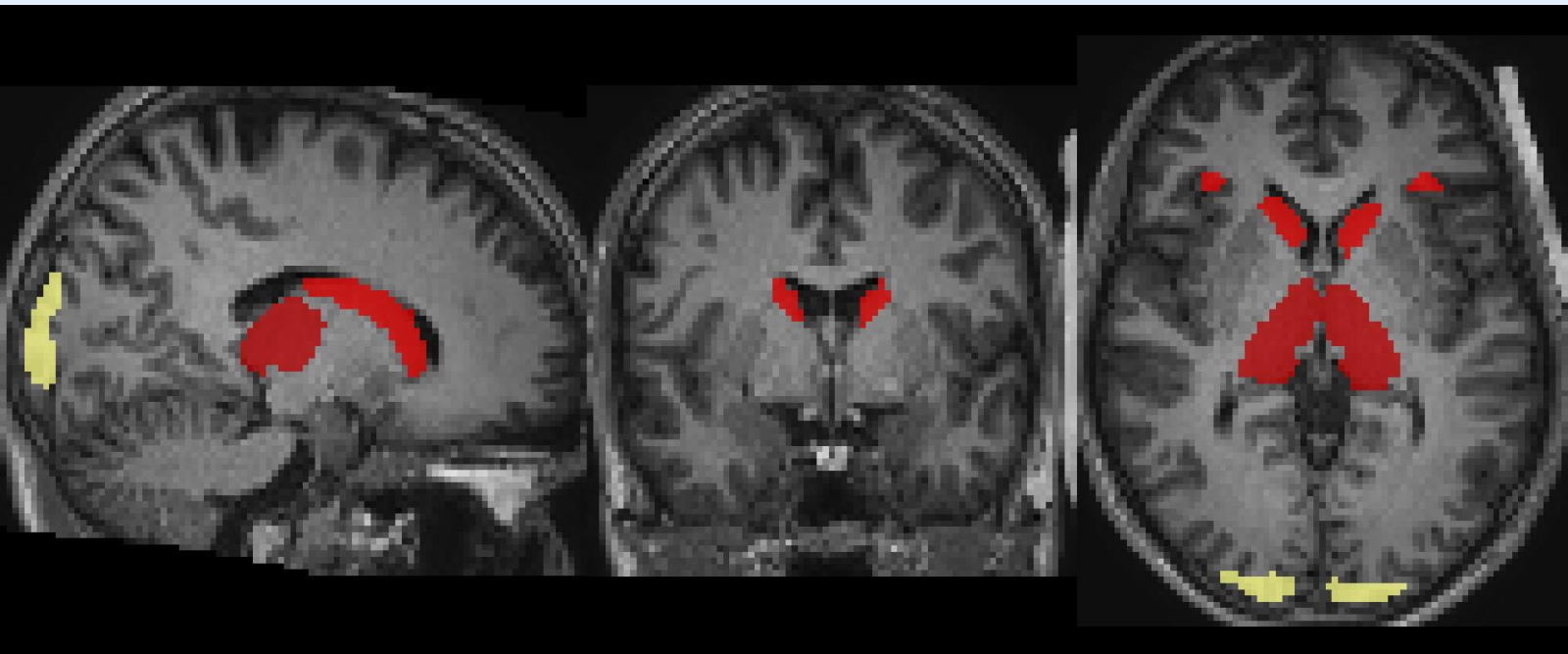
3. Wilcoxon ($p < 0.05 / (\text{num. test regions})$)



How much does EPI distortion correction impact rCBV?

Significant rCBV increase
EPIC Gradient Echo

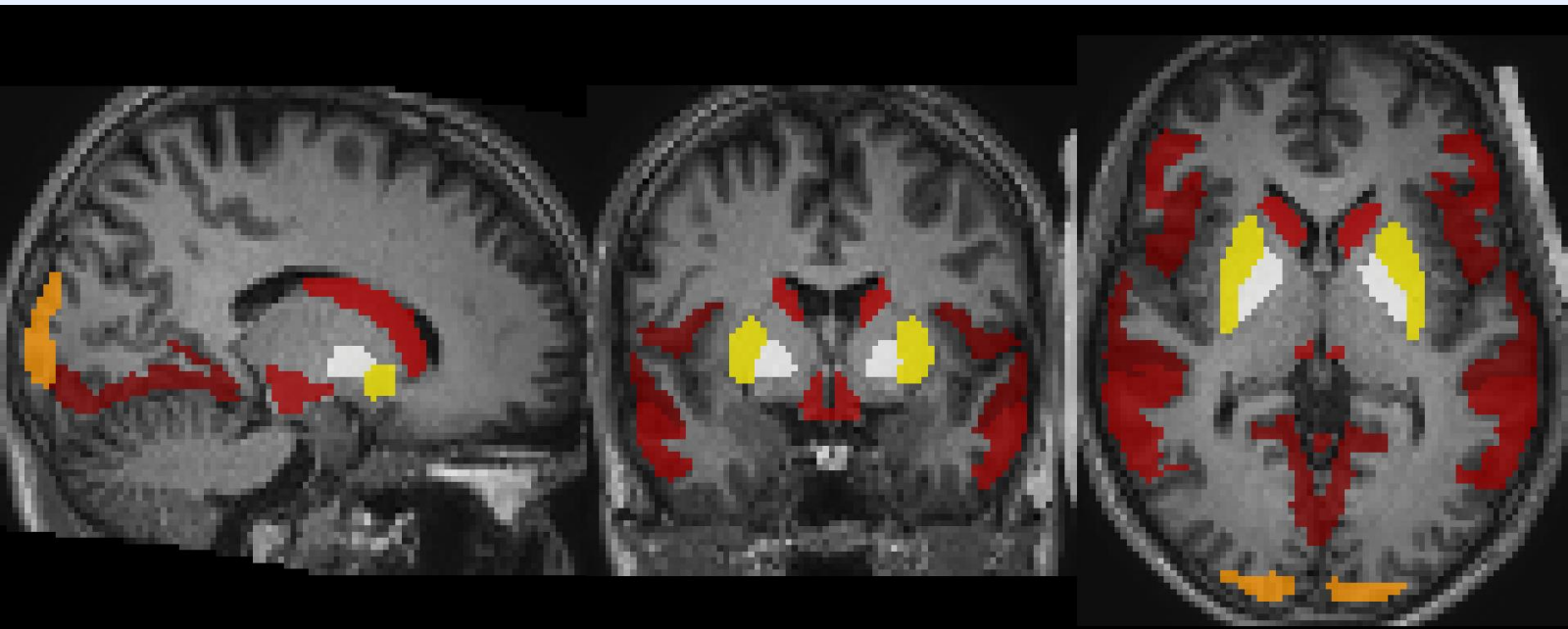
3. Wilcoxon ($p < 0.05 / (\text{num. test regions})$)



How much does EPI distortion correction impact rCBV?

Significant rCBV increase
TOPUP Spin Echo

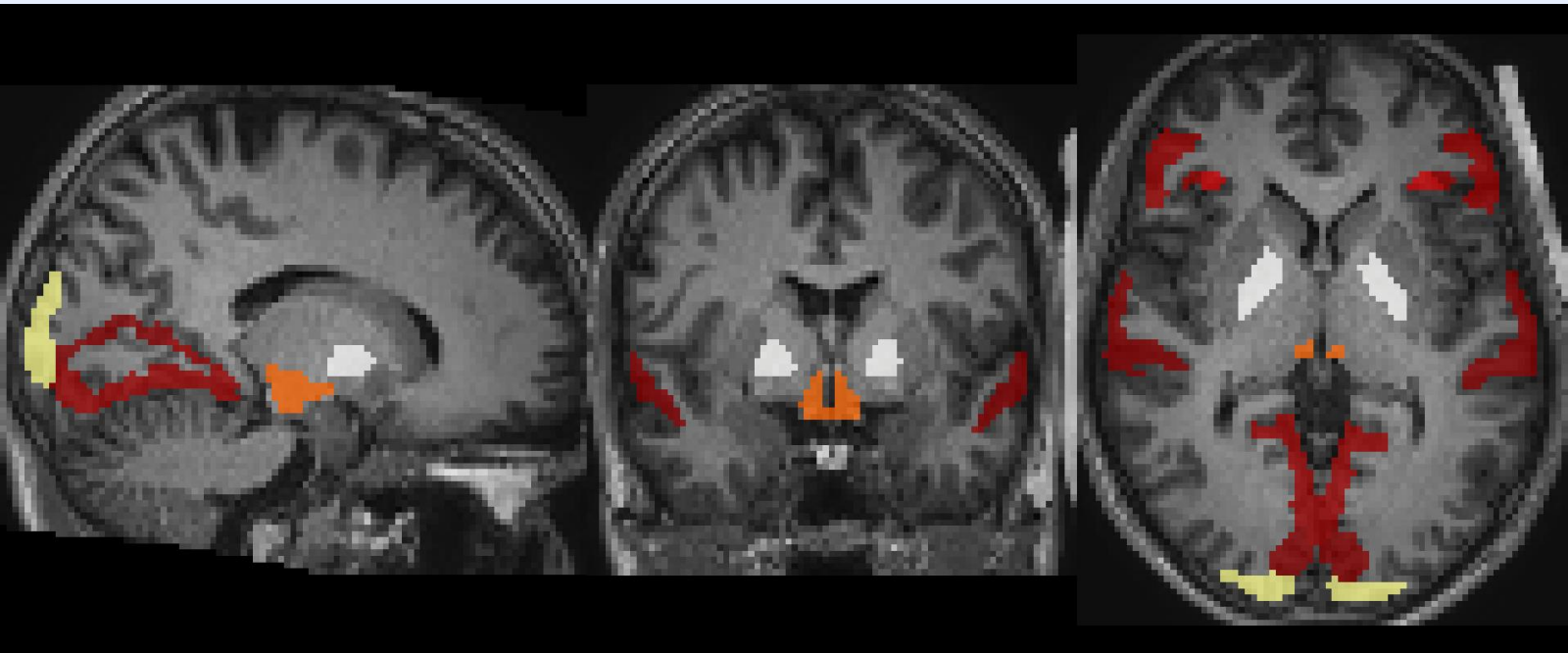
3. Wilcoxon ($p < 0.05 / (\text{num. test regions})$)



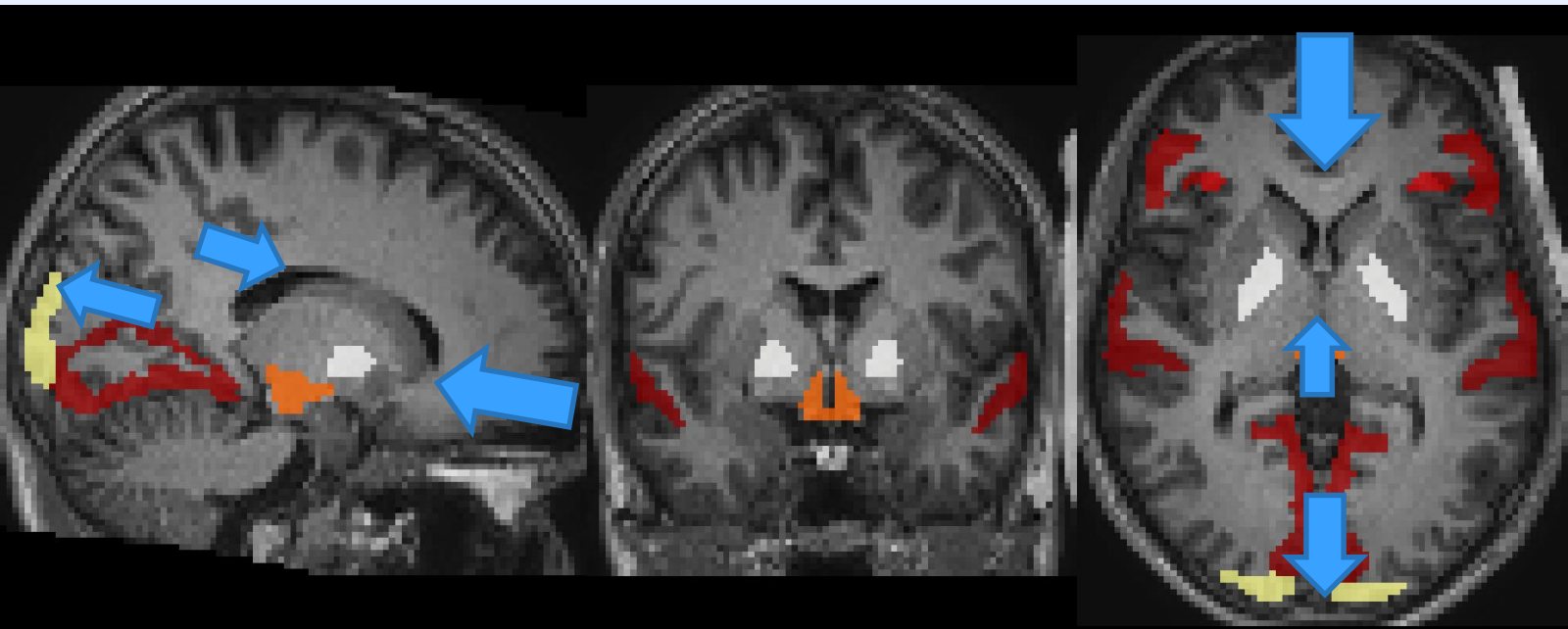
How much does EPI distortion correction impact rCBV?

Significant rCBV increase
EPIC Spin Echo

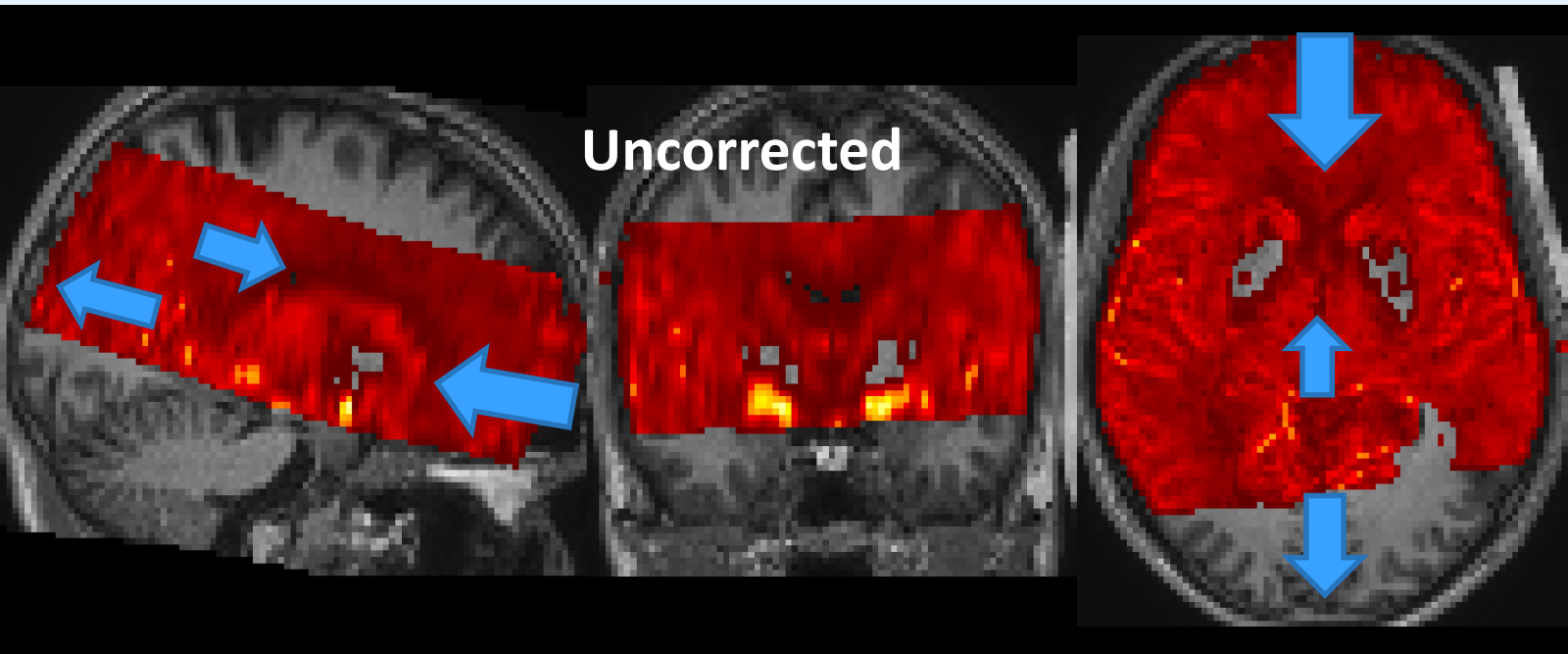
3. Wilcoxon ($p < 0.05 / (\text{num. test regions})$)



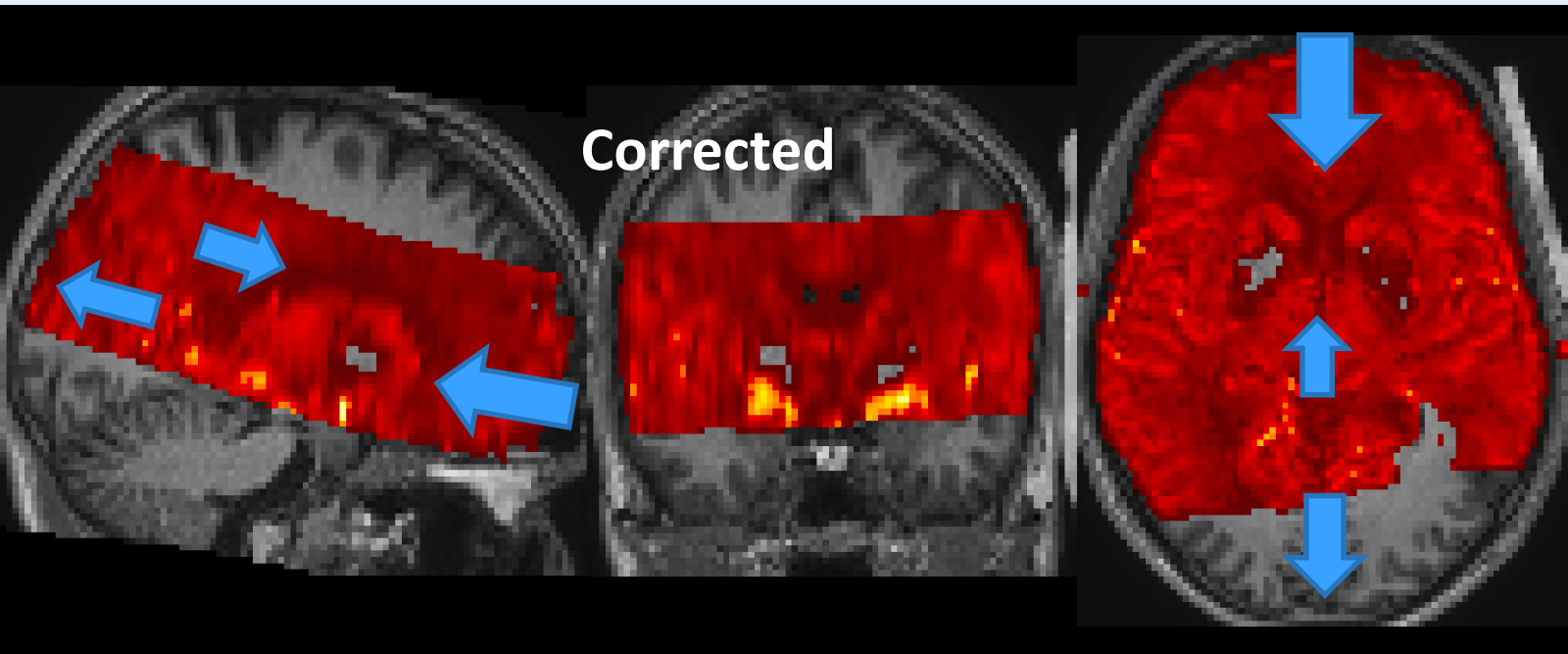
How much does EPI distortion correction impact rCBV?



How much does EPI distortion correction impact rCBV?



How much does EPI distortion correction impact rCBV?



Number of patients with tumor overlapping at least 500 voxels (4 cm³) of significant rCBV increase (N=45)

		GE TOPUP	GE EPIC	SE TOPUP	SE EPIC
	Number of significant regions (L, R merged)	6	6	16	13
> 4 cm ³ signif. rCBV increase	Enhancing ¹	5 (11 %)	3 (7 %)	25 (56 %)	13 (29 %)
	Necrotic ¹	6 (13 %)	1 (2 %)	15 (33 %)	6 (13 %)
	Edema ¹	19 (42 %)	12 (27 %)	32 (71 %)	21 (47 %)

Conclusion

- EPI distortion correction does have an impact on rCBV throughout the whole brain
- In this work; almost always rCBV *increase*
- Some vulnerable (statistical significant) regions are caudates, putamen, pallidum, gyrus rectus and occipital pole
- EPI distortion correction is necessary for pixel-perfect co-registration with non-EPI data, such as anatomical images and MR Elastography, which gives added value of vascular information from dynamic EPI-based MRI

Thank you!