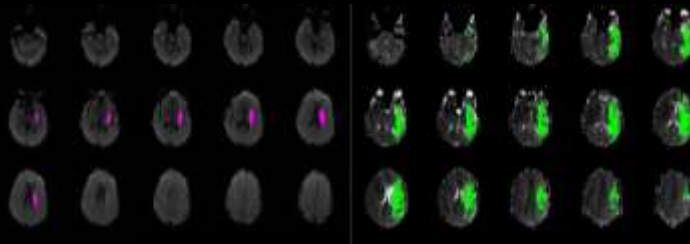
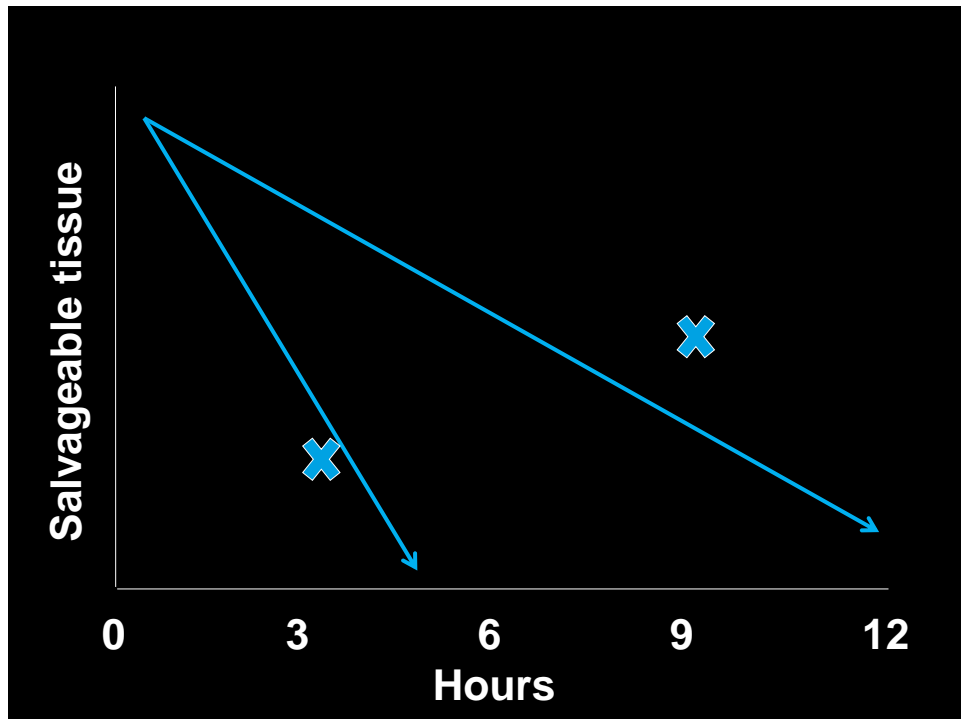


# Advanced Stroke Imaging



Greg Albers, MD  
Stanford Stroke Center



**The relationship between tissue viability and time is highly variable.**

**Accurate measures of irreversible core and salvageable penumbra**

## **DEFUSE STUDIES**



**MRI  
baseline**



**IV tPA (DEFUSE 1)  
Endovasc (DEFUSE 2)**



**MRI  
Post-treatment  
(reperfusion)**

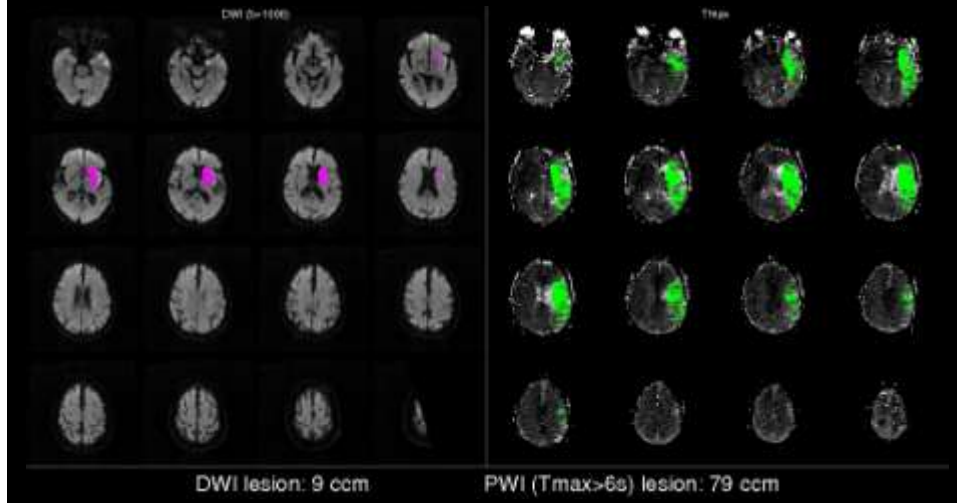


**MRI  
Day 5  
(FLAIR volume)**



**Clinical Assessment day 30  
and 90 (NIHSS and Rankin)**

## Automated MRI analysis program to outline and measure DWI and PWI lesions



## Are DWI lesion reversible following IV tPA at 3-6 hours?

The infarct core is well represented by the acute diffusion lesion: sustained reversal is infrequent

N=119

EPITHET-DEFUSE Investigators  
Journal of Cerebral Blood Flow & Metabolism (2012) 32, 50–56

6.7% with DWI reversal

Median volume 2.3 mL

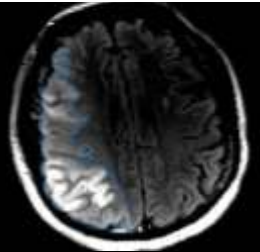
**Reversal of Early Diffusion-Weighted Magnetic Resonance Imaging Abnormalities Does Not Necessarily Reflect Tissue Salvage in Experimental Cerebral Ischemia**

Thomas M. Ringer, MD; Tobias Neumann-Haefelin, MD; Raymond A. Sobel, MD; Michael E. Moseley, PhD; Midori A. Yenari, MD

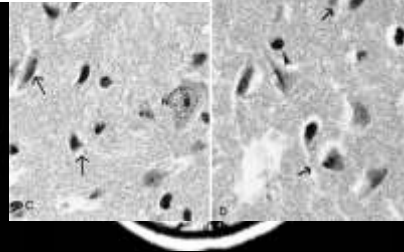
**Transient and Permanent Resolution of Ischemic Lesions on Diffusion-Weighted Imaging After Brief Periods of Focal Ischemia in Rats**

Correlation With Histopathology

Fidai Li, MD; Kai-Feng Liu, MD; Matthew D. Silva, BS; Toshiyoshi Onose, MD; Christopher H. Sotak, PhD; Joseph D. Fenstermacher, PhD; Marc Fisher, MD



Follow-up FLAIR  
"bright window"



Follow-up FLAIR  
"very bright window"

**DEFUSE 2**



Endovascular  
Therapy



MRI  
Post-procedure  
(reperfusion)



MRI  
Day 5  
(FLAIR volume)



Clinical Assessment day 30  
and 90 (NIHSS and Rankin)

Lansberg MG, et al. *Lancet Neurol.* 2012;11(10):860-7

# DEFUSE 2 Study

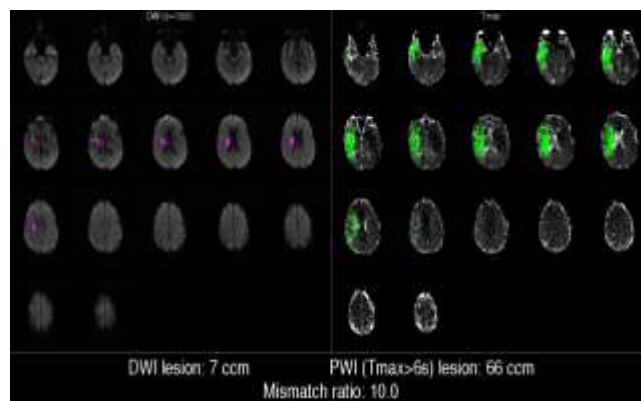
## Imaging Hypothesis #1

Baseline DWI lesions with  
ADC < 620 will be reliably  
incorporated into 5 day FLAIR

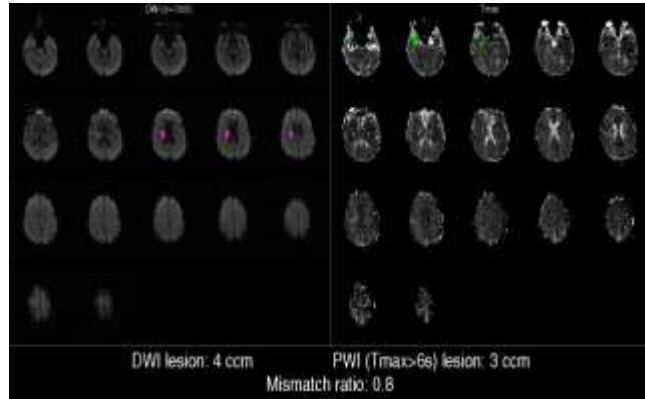
### RESULTS:

98% of the pixels with ADC < 620  
were incorporated into 5 day FLAIR

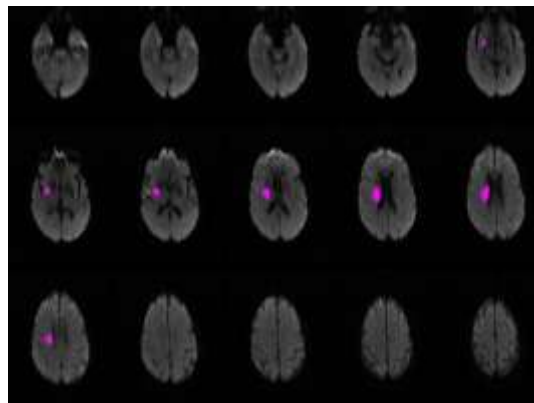
*Imaging Hypothesis #2:* What is the accuracy of DWI for predicting final infarct volume in patients who reperfuse?



Baseline DWI & PWI in a patient with successful  
reperfusion

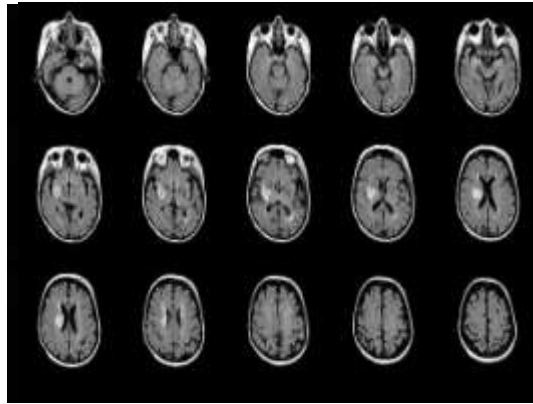


Post-procedure DWI & PWI




Baseline DWI & 5 Day FLAIR in a patient with successful reperfusion

What is the accuracy of DWI for predicting final infarct volume in patients with complete reperfusion?



Baseline DWI & 5 Day FLAIR in a patient with successful reperfusion

DEFUSE 2 

## Baseline DWI & Final Infarct Volume in patients with >90% Reperfusion

Predicted Final Volume vs. Observed Final Volume	Median (IQR)
Difference between baseline DWI and final infarct volume	5.6 ml (0.9-39.9)
How often did transient or permanent DWI reversal occur?	

DEFUSE 2 Investigators. Stroke. 2013;44:681-685

## Early DWI Reversal in DEFUSE 2 was Typically Transient

- 32% had early DWI reversal (median volume 33% of the initial DWI lesion).
- Median volume of permanent reversal at 5 days was 3 mL.
- Only 2 patients (3%) had a final infarct volume that was smaller than their baseline DWI lesion.

## Conclusion

DWI reversal following reperfusion is not uncommon, but is typically transient.

Early ADC reduction ( $<620$ ) is a very good surrogate for infarct core.



## Can PWI can estimate critical hypoperfusion with good accuracy?

Volumes obtained with appropriate **thresholding** match PET and Xenon CT measures of penumbra with very good sensitivity and specificity <sup>1-4</sup>

“The performance of  $T_{max} > 5.5$  sec vs. PET gold standard: to detect penumbral flow 88% sensitivity, 89% specificity <sup>4</sup> ( $< 20\text{mL}/100\text{gm}/\text{min}$ ) is excellent”

<sup>1</sup> Takasawa M et al. *Stroke*. 2008;39:870–877

<sup>2</sup> Olivot et al. *Neurology*. 2009; 31:72(13):1140-5.

<sup>3</sup> Zaro-Weber O et al. *Stroke*. 2010; 41:443-449

<sup>4</sup> Zaro-Weber O et al. *Stroke*. 2010; 41(12):2817-21.

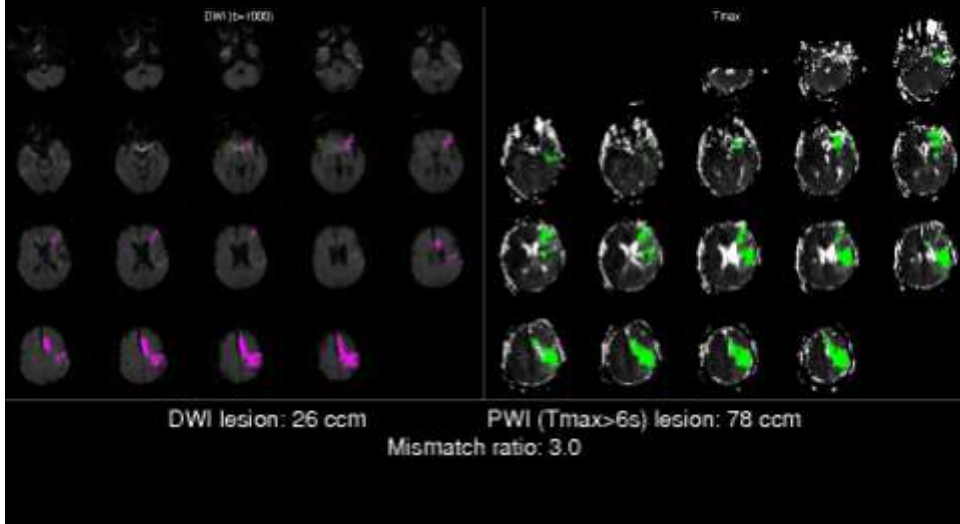
DEFUSE 2



## DEFUSE 2 Study

How accurate is the combination of early DWI and PWI volumes in predicting final infarct volume?

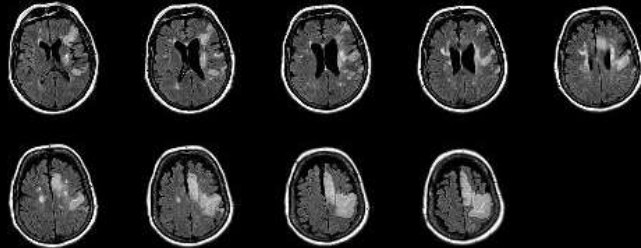
# 66 yo, NIH 18 Baseline DW/PWI

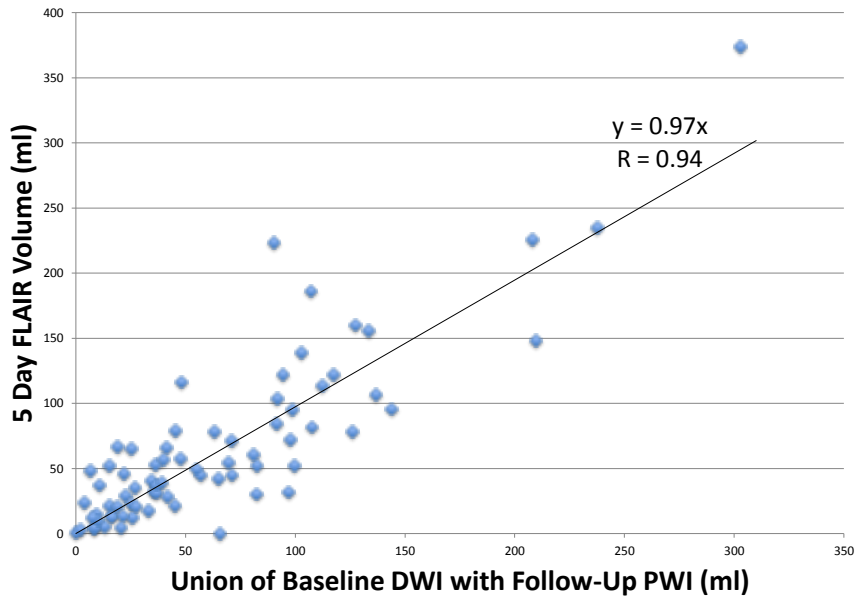


Post-procedure  
78 ccm Tmax > 6



5 day FLAIR  
73 ccm, NIH 15





Wheeler H, et al, *Stroke*. 2013;44:681-685

## Union of Baseline DWI & Early Follow-Up PWI Predicts Final Infarct

Predicted Final Volume vs. Observed Final Volume	Median (IQR)
Absolute value of difference between predicted & final infarct volume	15.0 ml (4.8-32.8)
Difference between predicted and final infarct volume	-0.1 ml (-19.8-12.5)

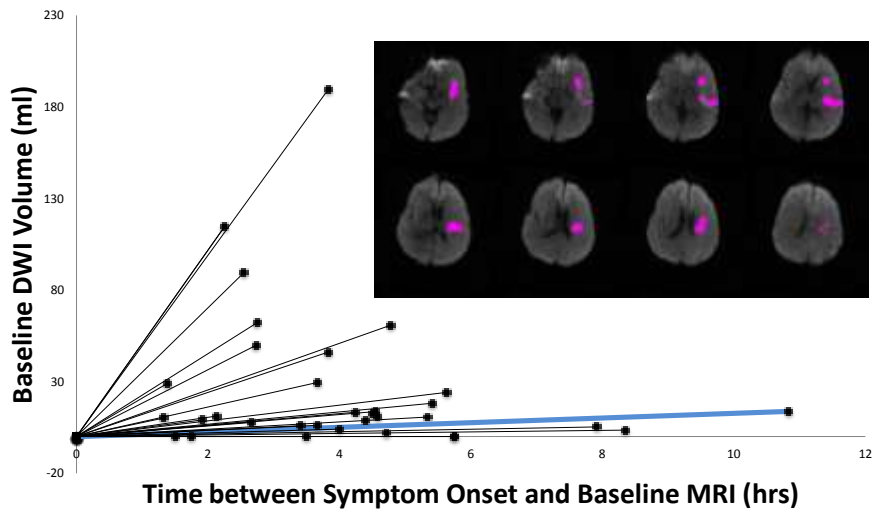
Wheeler H, et al, *Stroke*. 2013;44:681-685

# What About Time?

Do different patients have different time clocks?

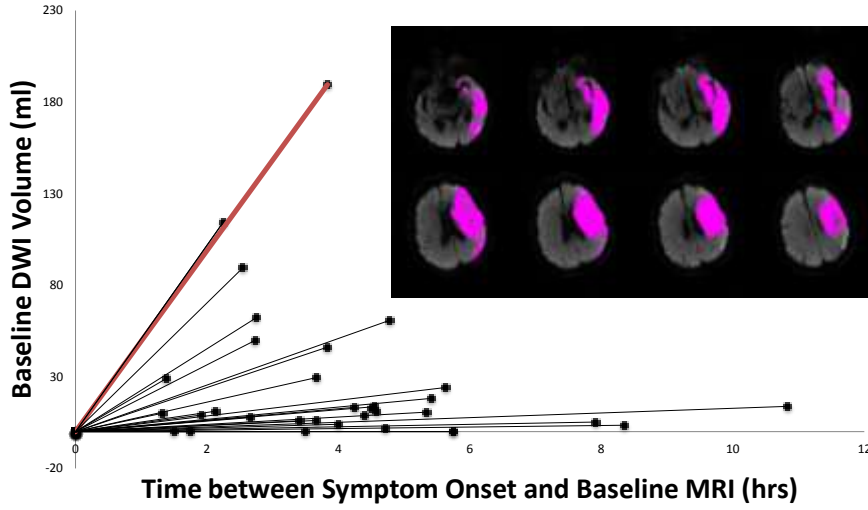
DEFUSE 2

Initial Growth Rate in 33 Patients with Known Onset & MCA M1 Occlusion

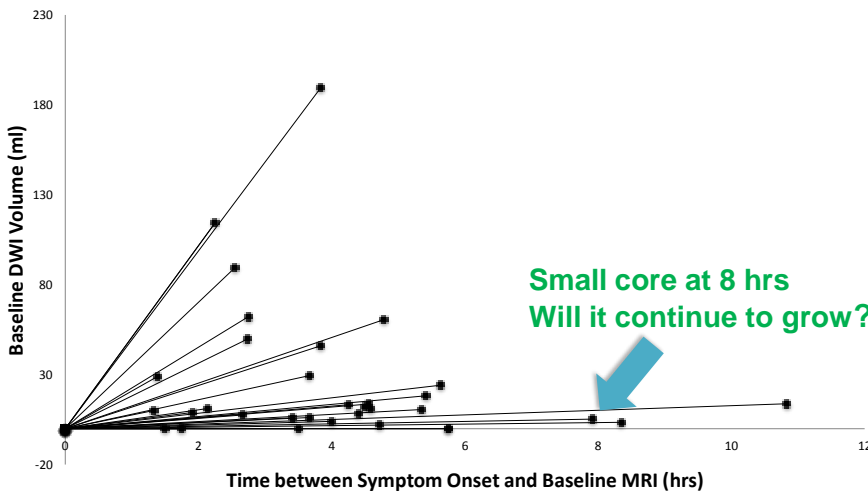


DEFUSE 2

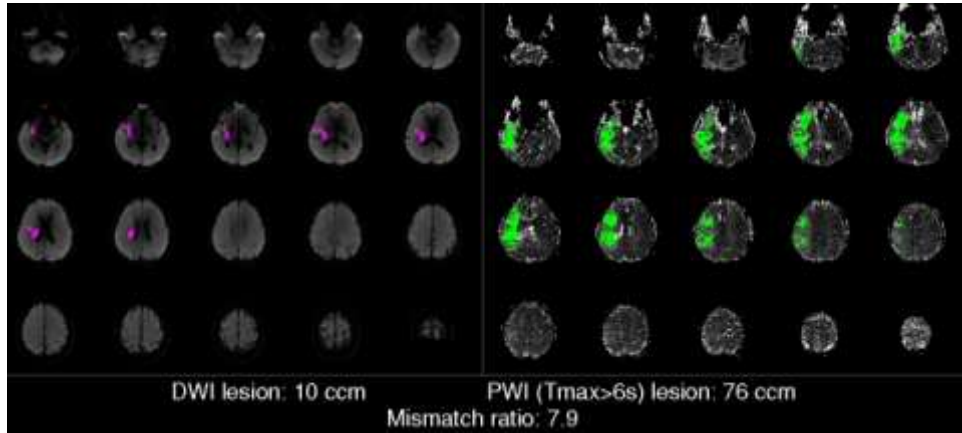
Initial Growth Rate in 33 Patients with Known Onset & MCA M1 Occlusion



Initial DWI Growth Rate in DEFUSE 2 Patients with M1 Occlusions

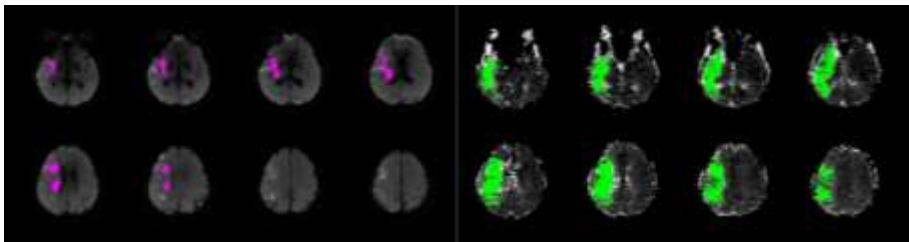


# 66 yo M; MRI 8 hrs after witnessed onset

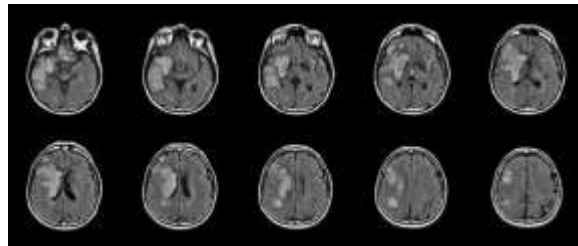


10-006

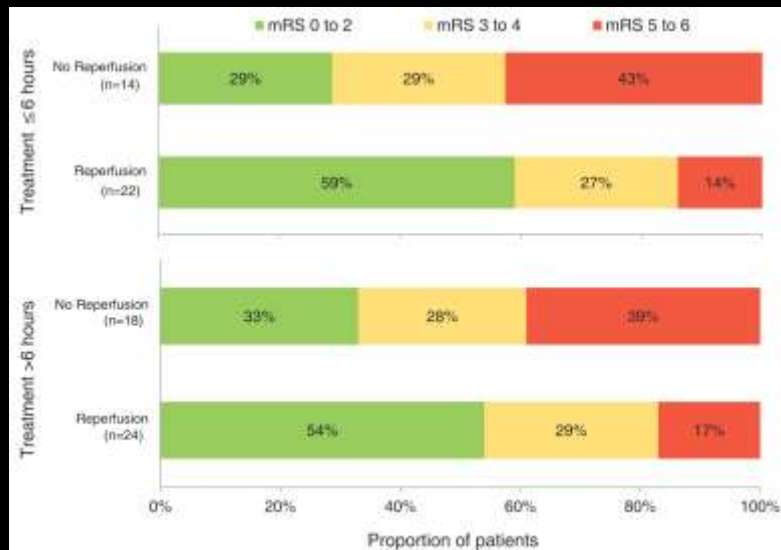
# No reperfusion; Follow-up MRI 12 hrs after symptom onset



Day 5 FLAIR



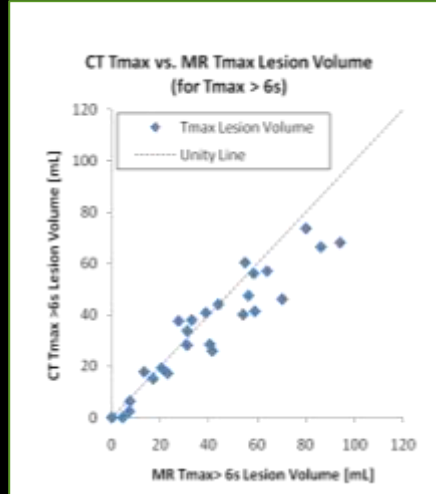
## DEFUSE 2 Target Mismatch patients



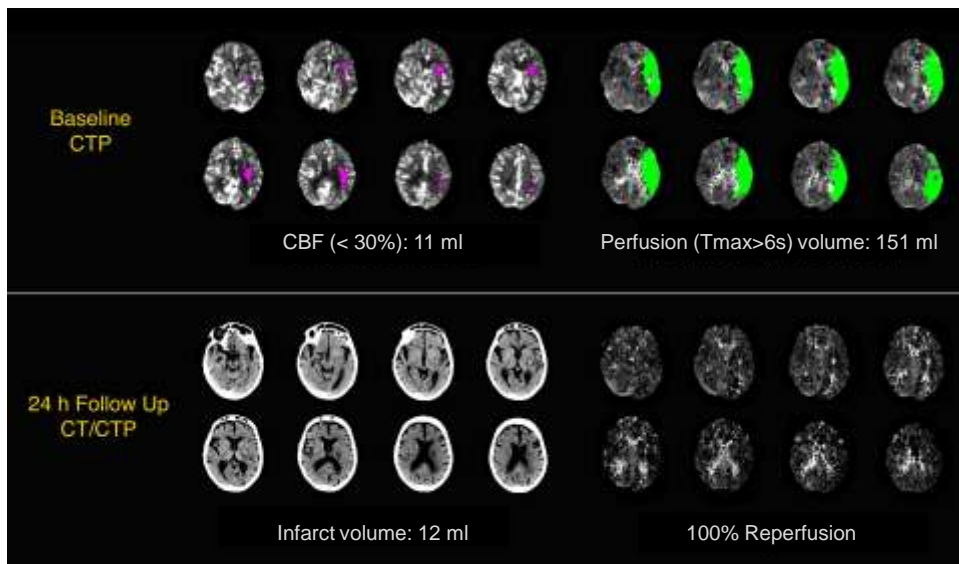
**Access to hyperacute MRI is limited**

**Can CTP image core and penumbra?**

# CT Perfusion Tmax >6s volume predicts MRI Tmax >6s volume

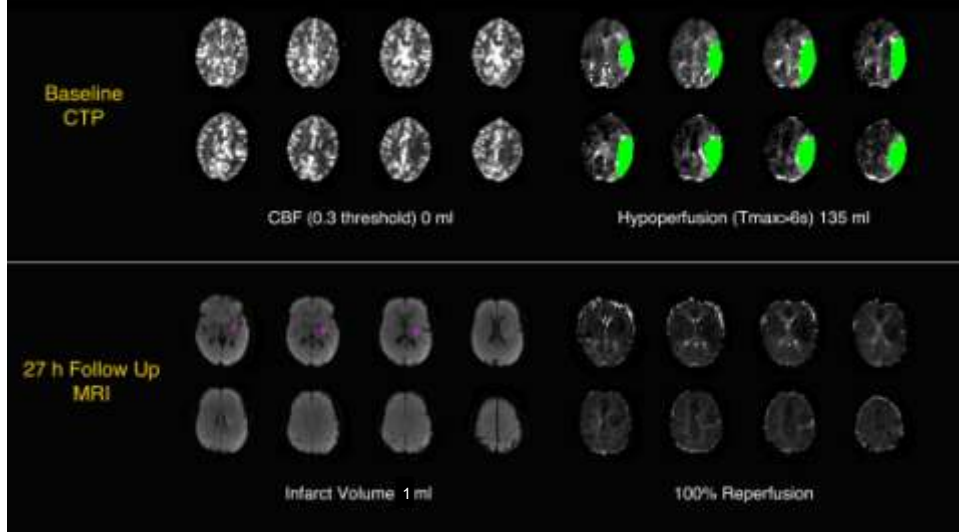


## CT Perfusion imaging of core and penumbra

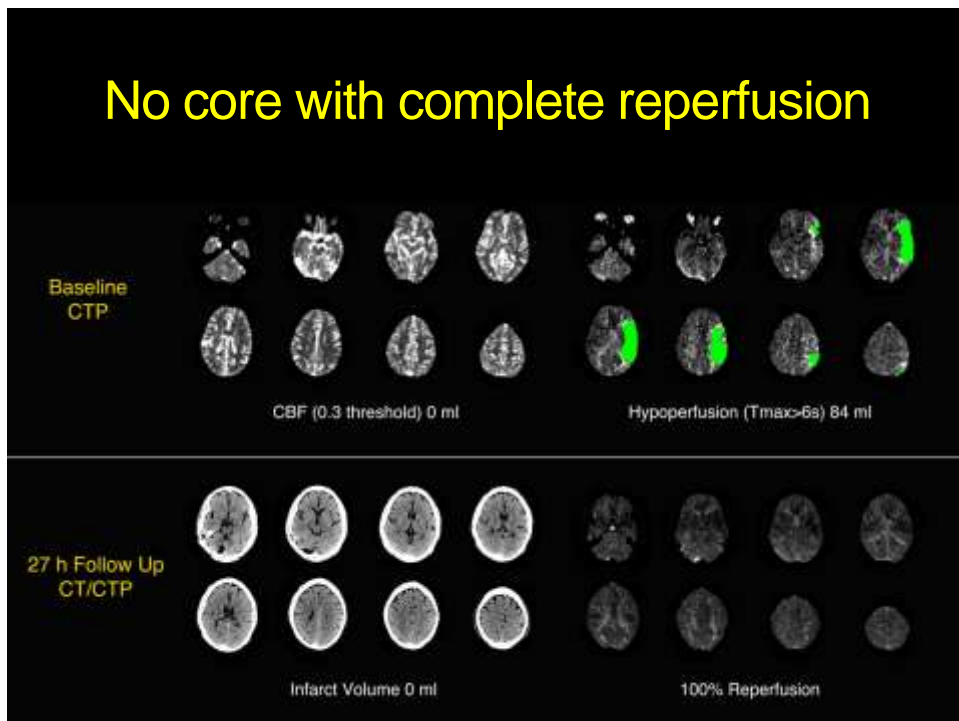




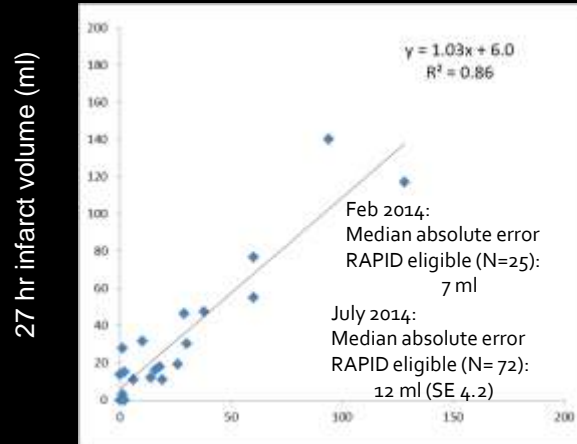
## No core with complete reperfusion



## No core with complete reperfusion



# Accuracy for Prediction of Infarct Volume



Union of baseline CORE volume + 27 hr PWI Tmax >6 hypoperfusion volume (ml)