Comparison of Arterial Input Functions by Magnitude and Phase Signal Measurement in DCE-MRI of brain patients treated with Radiosurgery

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Disclosures & Acknowledgements

- Patented Phantom technology
- Modus Medical Devices Inc.
  - Commercialization License Contrast CT QA
- Shelley Medical Imaging Technologies
  - Commercialization License DCE Phantom

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Reproducibility of Dynamic Contrast-enhanced MR Imaging

Part II. Comparison of Intra- and Interobserver Variability with Manual

Radiology

Imaging

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60-3016/$–see front matter

Reproducibility of Dynamic Contrast-enhanced MR Imaging:

Why We Should Care[1]

Vicky Goh, MBBChir, MRCP, FRCR, MD
Tobias Schaeffter, PhD
Martin Leach, PhD

Dynamic contrast material–enhanced (CE) magnetic resonance (MR) imaging enables tumor vascular physiology to be assessed. By kinetic modeling of signal intensity changes resulting from the passage of contrast agent through the tumor vascular bed, physiologically based parameters, including volume transfer constant (K^{trans}), rate constant (k_{ep}), extravascular extracellular volume fraction (v_e), and plasma volume, can be derived that may reflect tumor perfusion, vascular

also been stressed by the recent Quantitative Imaging Biomarker Alliance initiatives, supporting a reduction in measurement uncertainty to a coefficient of variation of less than 20% (5).

The results of two studies by Heye et al (6,7) published in this issue of *Radiology* stress the difficulties of performing dynamic CE MR imaging across different commercially available software platforms in clinical practice, but more important suggest a potential solution. In part 1, Heye et al (6) high-

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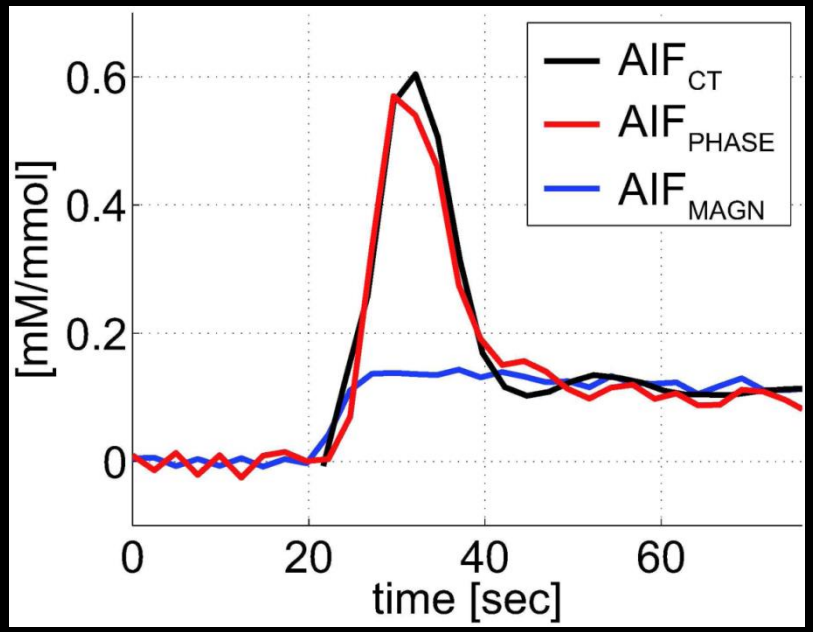
Challenges in MR Signal Quantification

- Difficulty measuring signal enhancement due to inflow effects, B1 non-uniformity, saturation effects
- Model-based / population average / individually measured
- Measured AIF differs from population average in 20% patients (Port, Magn Reson Med, 2001)



Prostate
Flip Angle 8º

Korporaal *et al*, Magn Reson Med, 2011

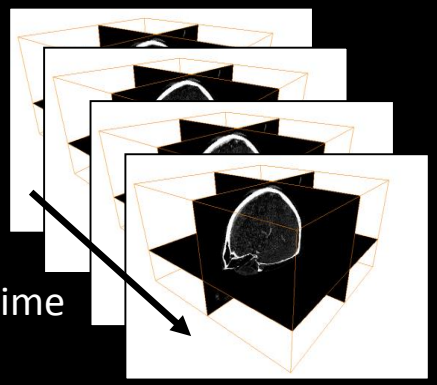
Perfusion Imaging - Marker of Early Response

Given CT signal linearity to contrast concentration:

1. Compare DCE-MRI to volumetric DCE-CT as a perfusion imaging biomarker

2. Explore various factors which contribute to differences between DCE-CT and DCE-MR metrics in the same patient

Methods: Temporal Dynamic Analysis (TDA)



4D DCE CT

4D DCE MR

voxel

Signal to Concentration Conversion

$$S_o = S \frac{\left(1 - e^{-\frac{TR}{T_{10}}} \cos\alpha\right)}{\left(1 - e^{-\frac{TR}{T_{10}}}\right) \sin\alpha}$$

$$[Gd(t)] = \frac{1}{R}\left[R_1^*(t) - R_1^*(1)\right]$$

Automated Voxel-based Analysis of 4D DCE CT data improves the measurement of serial changes in tumor vascular biomarkers - Coolens *et al* 2014 – IJROBP. 91(1) pp. 48-57

Methods: DCE Imaging

DCE-MRI

- Verio 3T System (IMRIS)
- VFA T1 Quantification (10, 20°) (1 x 1 x 5 mm)
- 3D-FLASH: matching echo times (1.86msec), repetition times (4.8msec) t = 5s
- Gadolinium injection (Magnevist 20cc),
- Reconstructed Matrix resolution: 1.5 x 1.5 x 3mm

Volumetric DCE-CT

- Reconstructed Matrix resolution: 0.5 x 0.5 x 1mm
- Volumetric DCE CT on 320-slice CT with Visipaque®320 injection at 5ml/sec
- VIF measured both in Carotid Artery and Sagittal Sinus

- Image registration both intra-DCE and inter-modality

Methods: Kinetic Parameter Sensitivity

- Sensitivity to Arterial Input Function (AIF)

  DCE MRI (Sagittal Sinus)

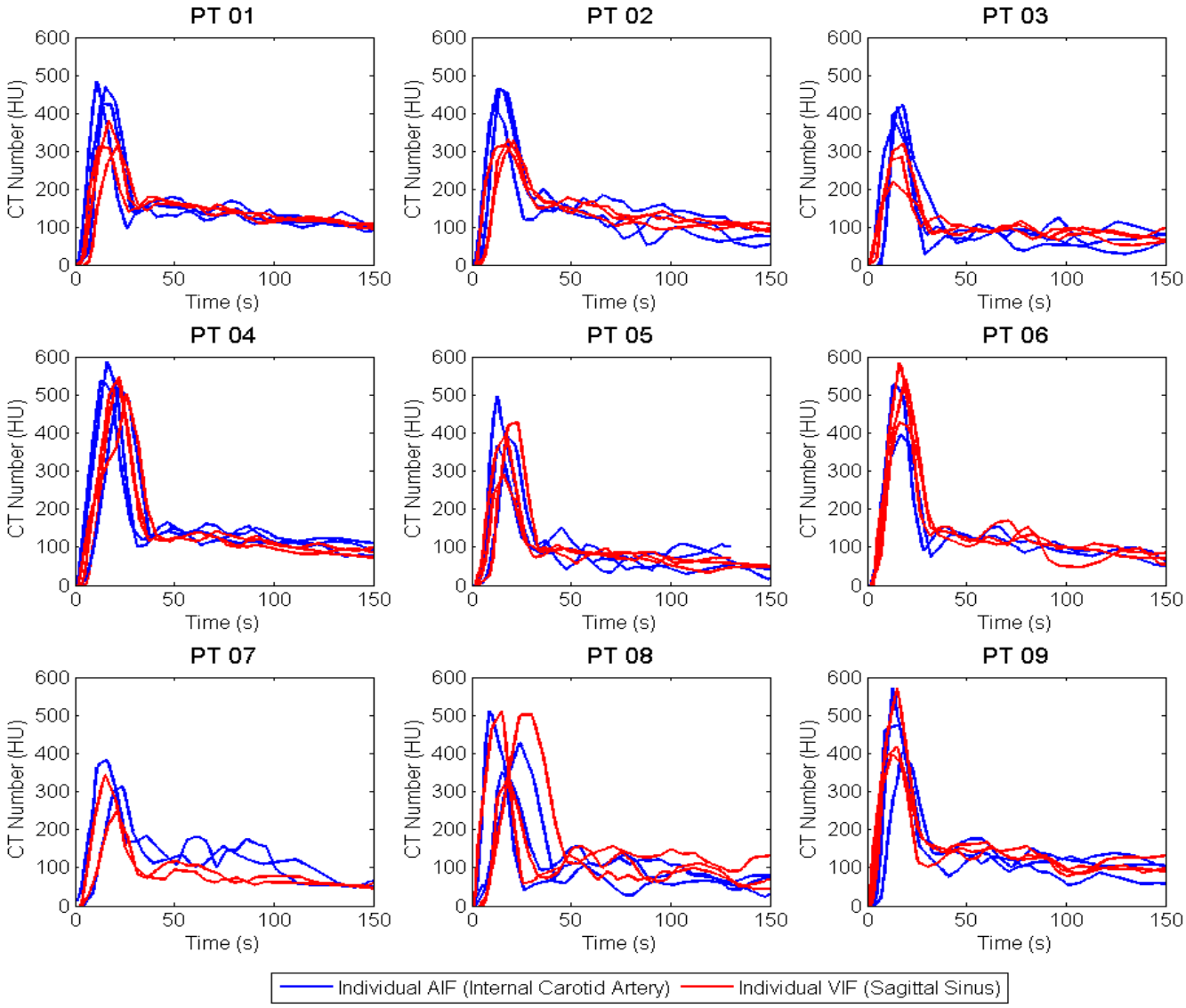
  - Population-based AIF
  - Phase AIF
  - Magnitude AIF

  DCE CT

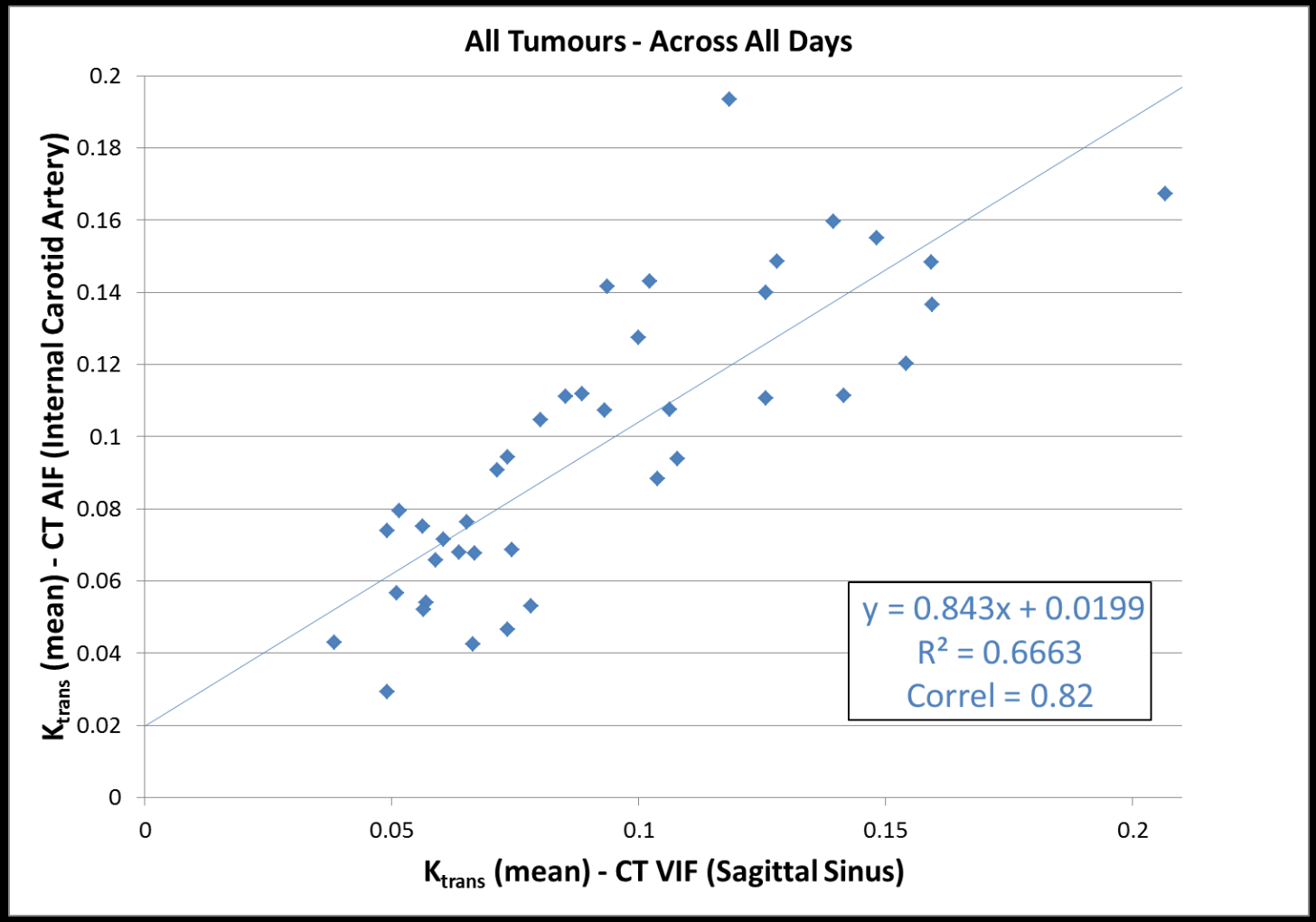
  - AIF (Carotid)
  - VIF (Sagittal Sinus)

- Sensitivity to pre-contrast longitudinal relaxation time
  - voxel-based T_{10}
  - Fixed value

Results: Variation in CT AIF

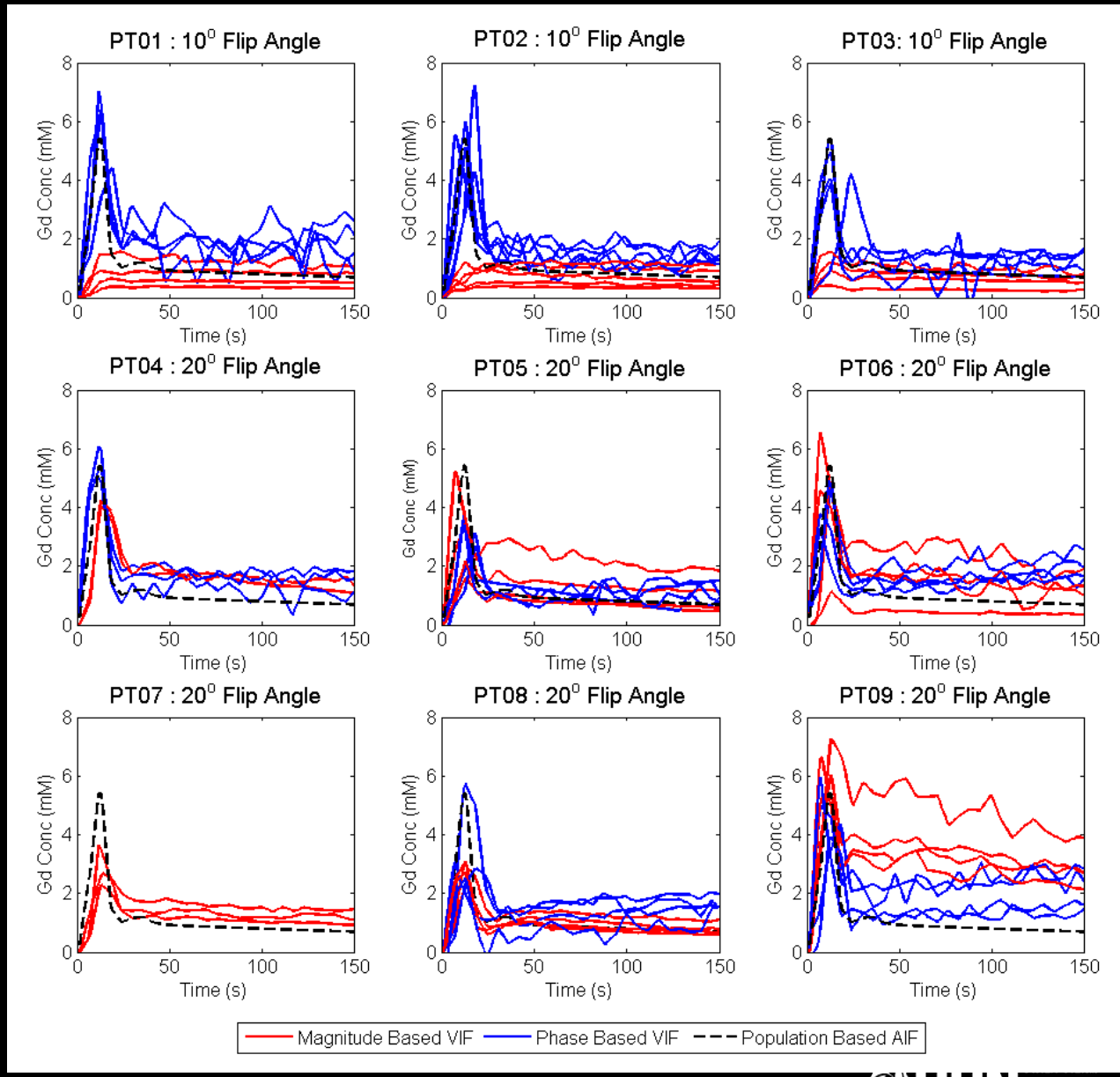


Results: CT AIF vs. CT VIF (Absolute K_{trans})

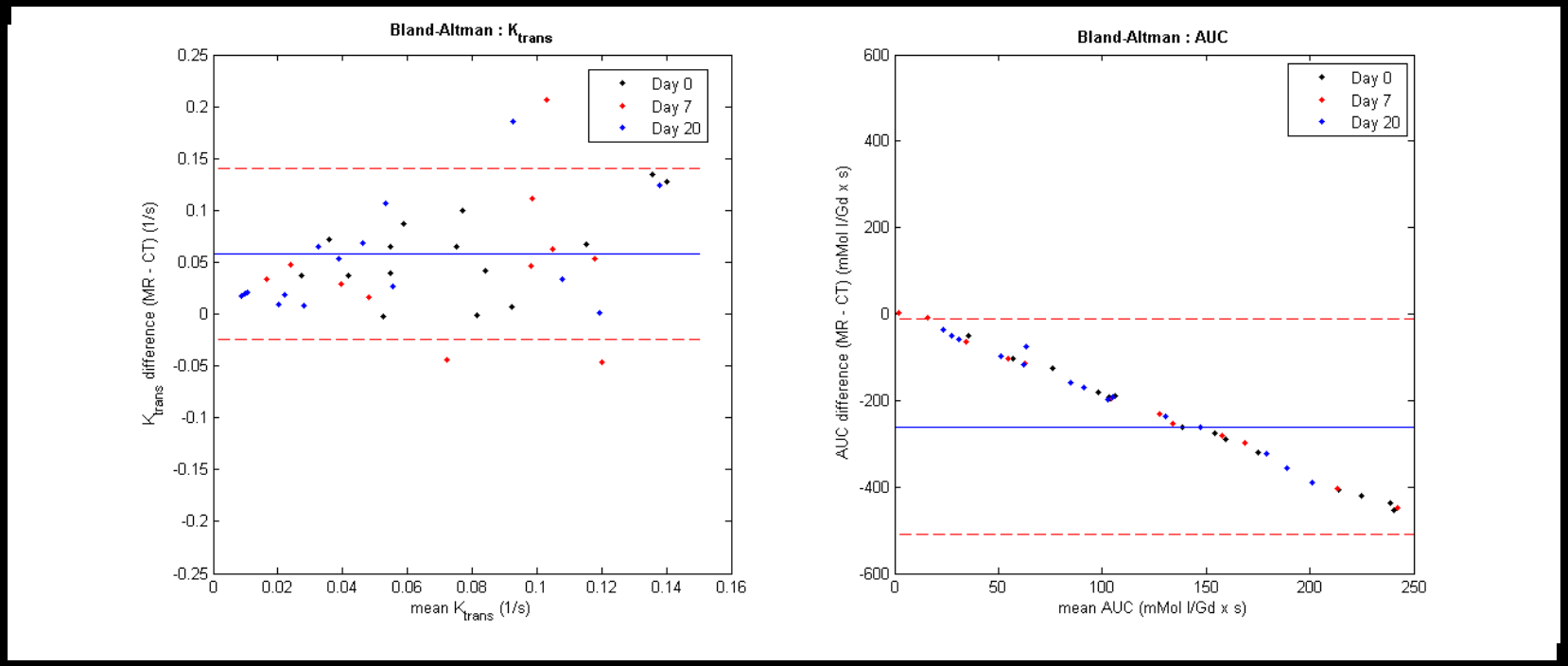


Results: Variation in MR AIF

- First 3 Patients scanned with a 10° flip angle
  - Magnitude VIF severely underestimated
- Next 6 Patients scanned with a 20° flip angle.
  - Magnitude VIF improved
  - Phase based VIF starting to fail



Results: Perfusion CT vs. MRI (median K_{trans})

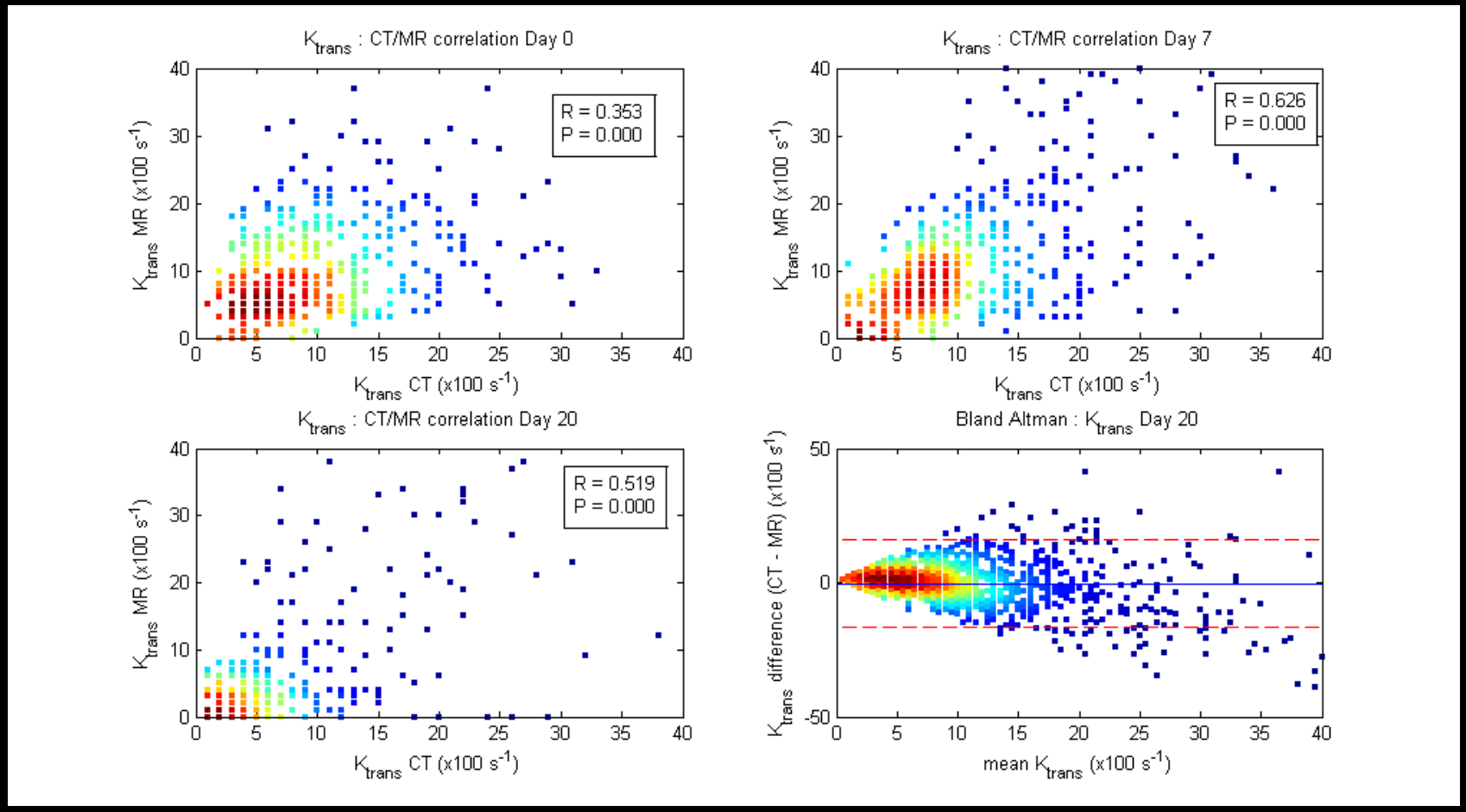


Statistically significant, moderate correlations for all days using AIF_{pop} and voxel-based T_{10} maps.

K_{trans} : $R^2 = 0.5$ (P=0.05)
AUC : $R^2 = 0.6$ (P=0.02)

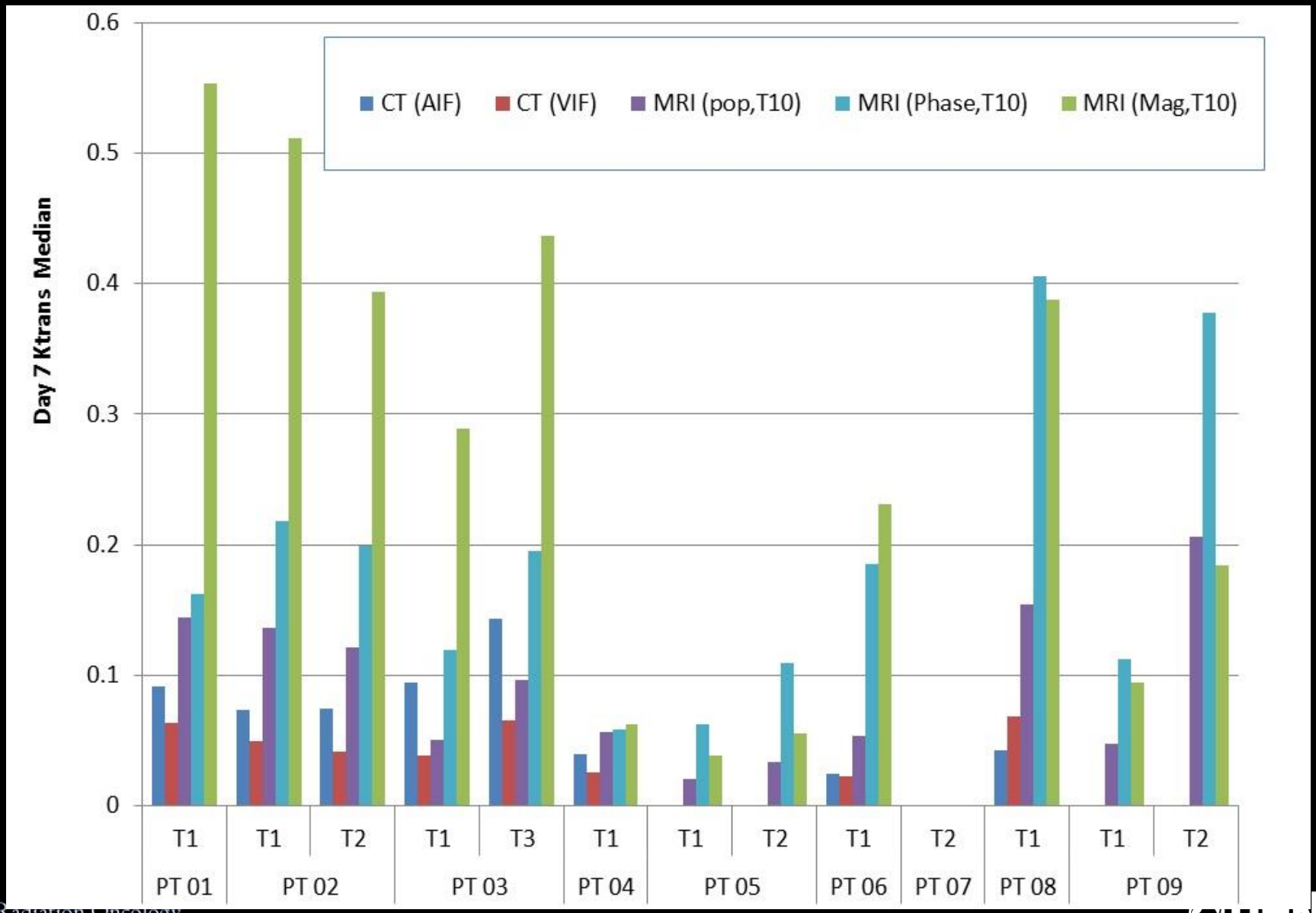
Median value in 3D tumor volume

Results: Perfusion CT vs. MRI (voxel-voxel)

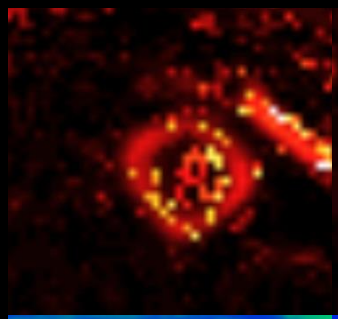
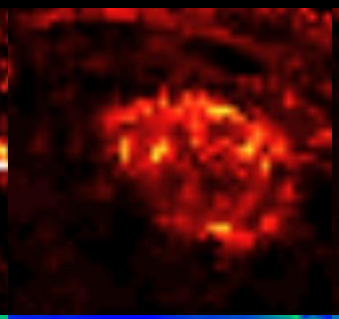
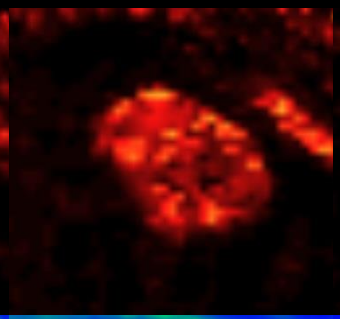
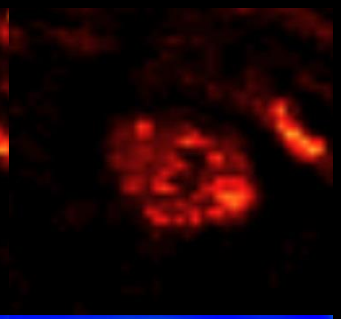
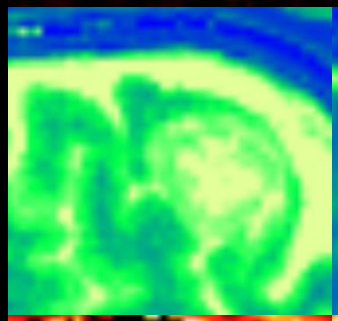
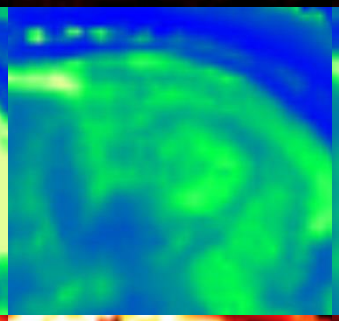
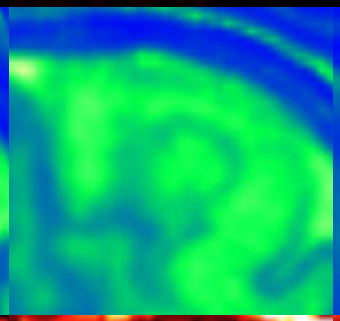
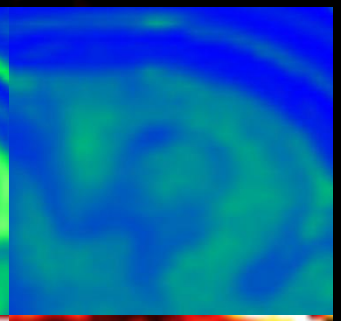
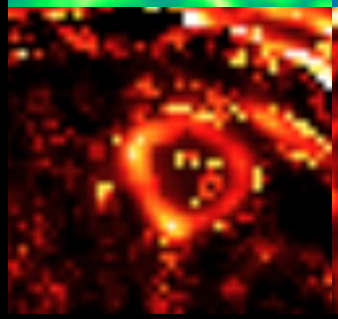
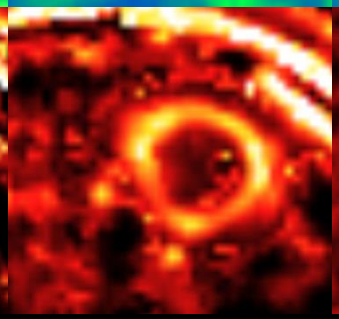
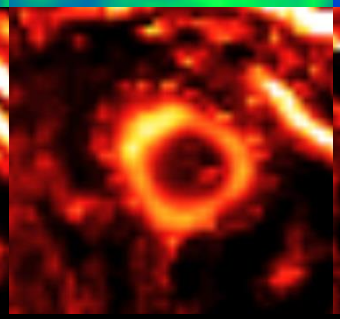
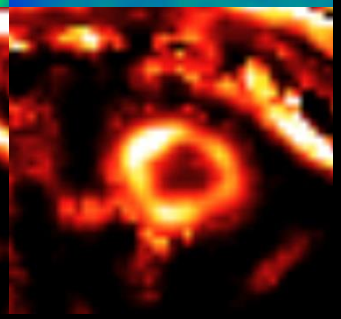


AIF_{pop} and voxel-based T_{10} maps

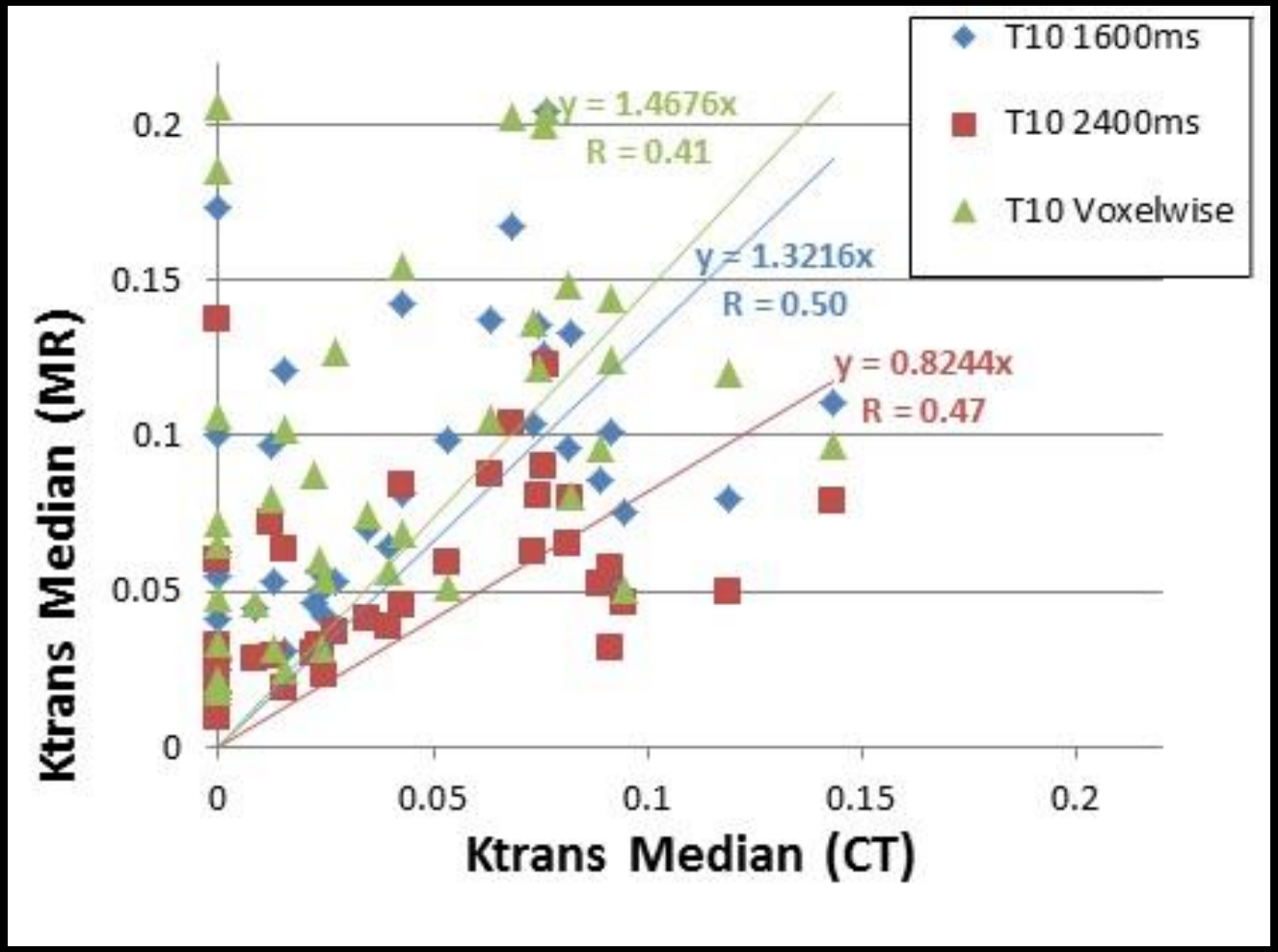
Results: Measured Magnitude vs Phase AIF



Results: T_{10} dependency (K_{trans})

	Pre-SRS (Day 0)	Post-SRS (Day 3)	Follow Up (Day 7)	Follow Up (Day 20)
K_{trans} w static $T1_0$ = 2400 ms				
$T1_0$ Map				
K_{trans} with Ind $T1_0$ Map				

Results: T_{10} dependency (K_{trans})



Discussion

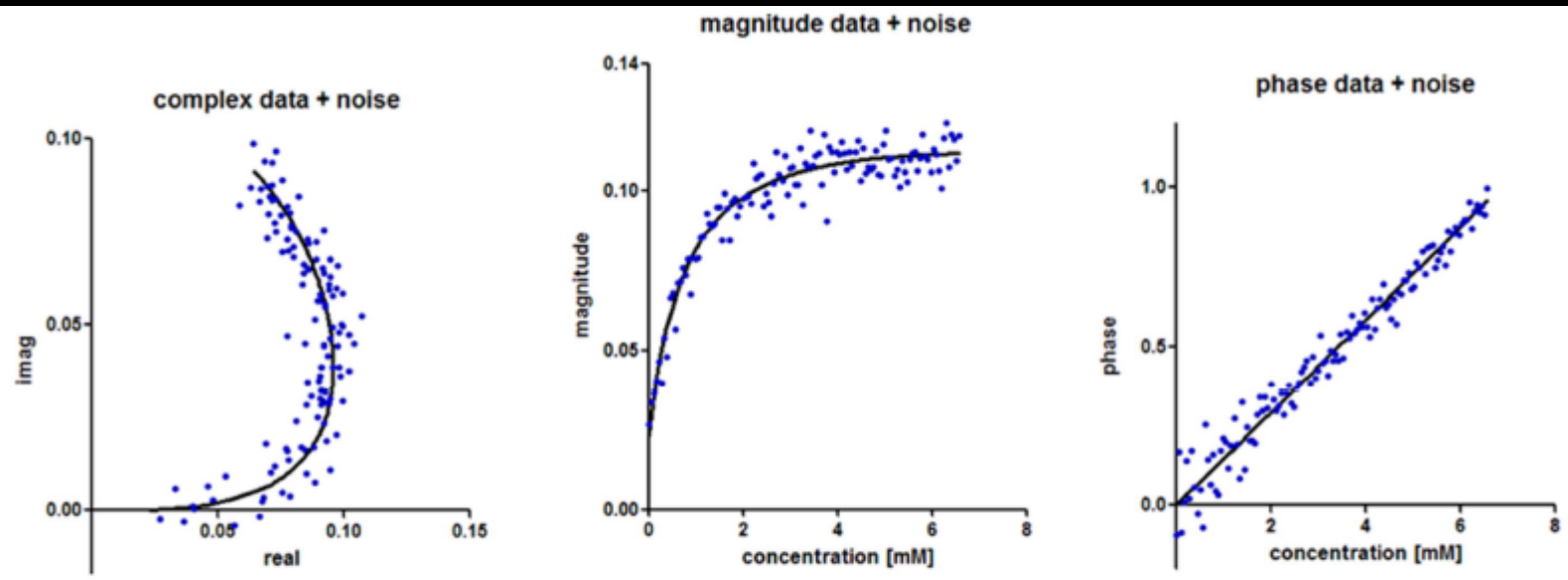


Fig. 1. *Influence of noise on concentration determination. Although the complex noise is equal over the complete signal, the error it causes when using magnitude data is larger at higher concentrations. The error in phase data is larger at smaller concentrations*

Courtesy: Simonis, Utrecht. ISMRM 2015

Conclusions

- First study evaluating perfusion parameters acquired by same-day volumetric DCE-CT and DCE-MRI using same voxel-based analysis platform
- Volumetric DCE-CT parameter stability with VIF
- Statistically significant dependencies on AIF and T_{10} measurement accuracy
- Absolute K_{trans} correlations between DCE-CT and MRI are significant, even on voxel-voxel basis, when using voxel-based T_{10} maps
- Highest correlations at Day 7 post SRS (likely due to small tumor size at Day 20) and possible predictor of response

Thank You

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