

Repeatability of DCE-MRI improves with the Constrained Reference Region Model

Zaki Ahmed¹ & Ives R. Levesque² ¹Corewell Health William Beaumont University Hospital, Royal Oak, MI
²Medical Physics Unit, McGill University, Montréal, QC

Introduction

Problem: Quantitative DCE-MRI gives K^{trans} , k_{ep} , and v_e . These can be useful for classifying tumors & assessing treatment response, but the repeatability is poor.

Cause: Most models need an arterial input function (AIF) which is difficult to measure. Poor AIF measurement could be responsible for poor repeatability.

Solution: The reference region model (RRM) is an alternative which doesn't need an AIF. RRM should then be more repeatable than AIF-based models

Goal: To test if RRM & Constrained RRM (CRRM)^[1] can improve repeatability.

- RRM is a 3-parameter model, but one of the fitted terms describes the reference tissue
- CRRM does two fits, the first has 3-parameters and second fit has 2-parameters by fixing the ref.tissue term to an estimated value

Materials & Methods

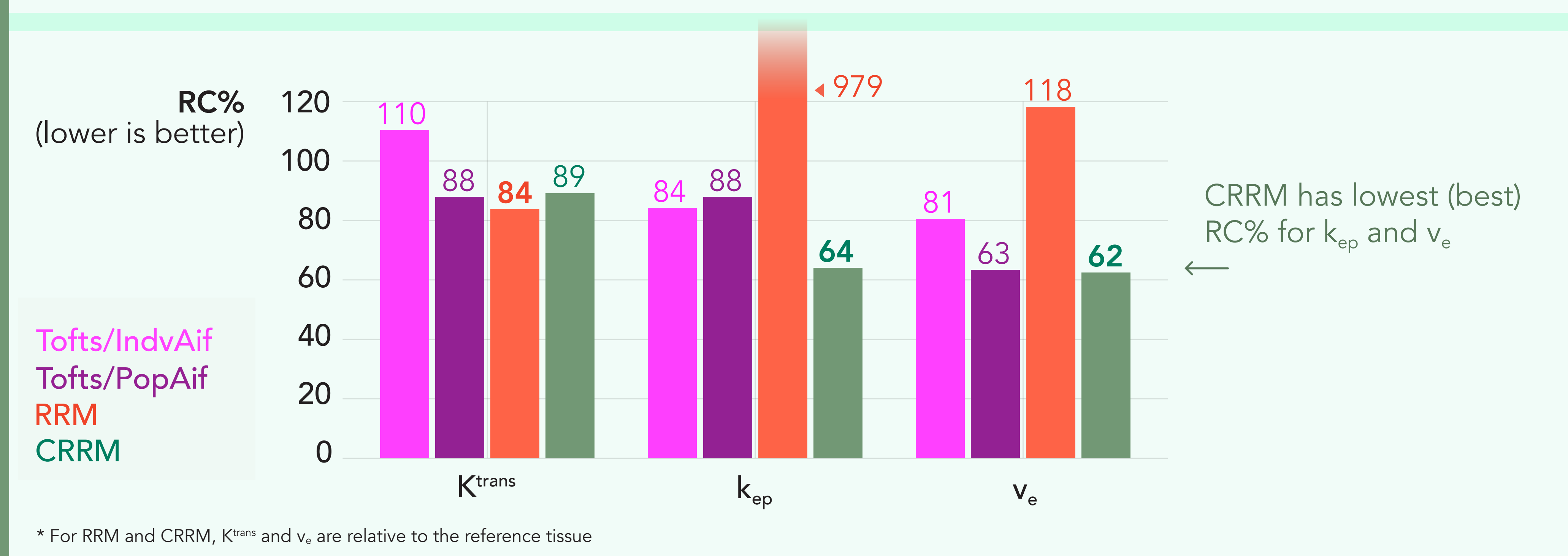
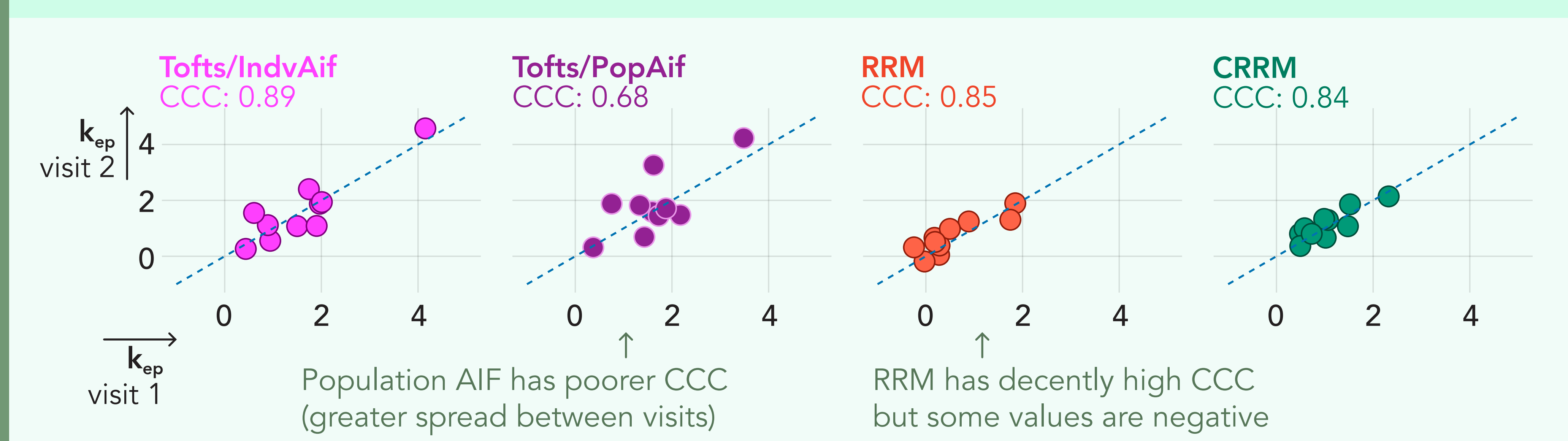
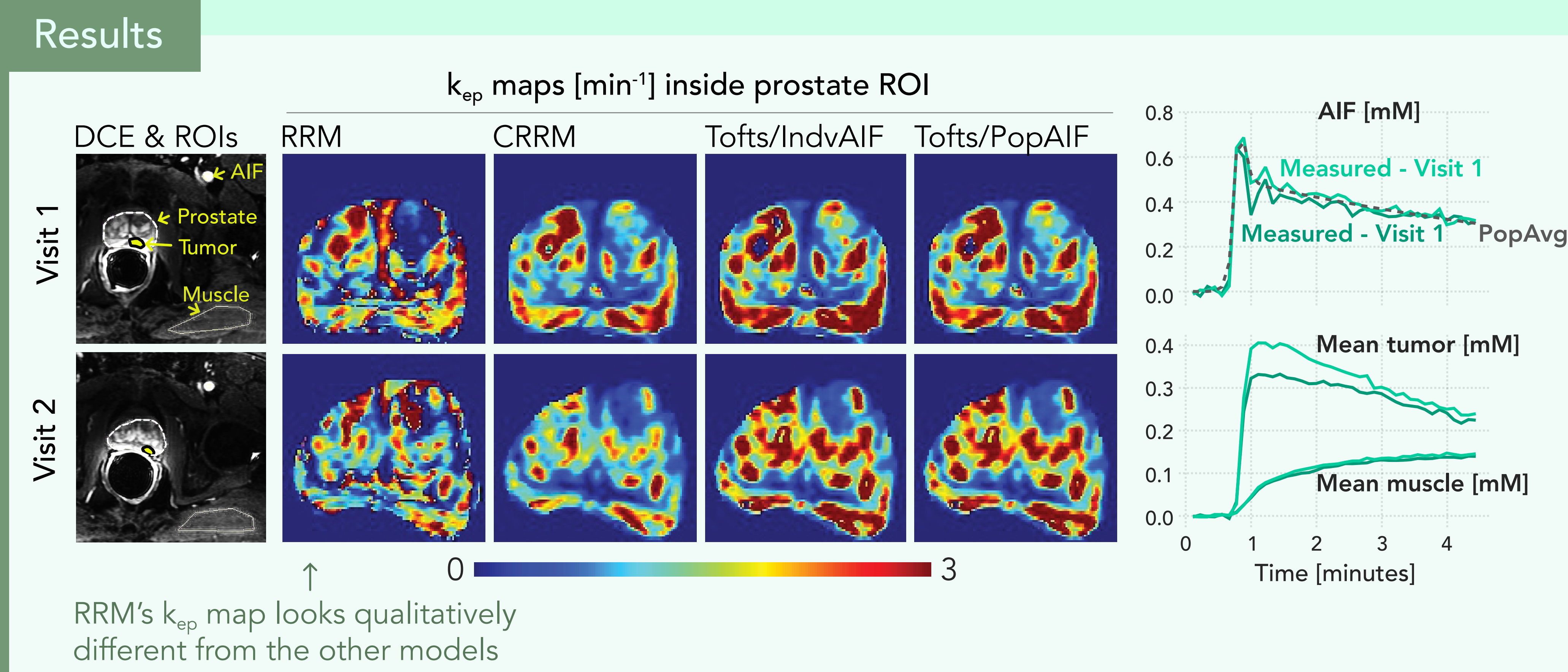
Data: 20 Prostate DCE-MRI exams from a publicly available dataset^[2] (10 subjects, 2 visits each)

Models: Tofts model with (i) measured and (ii) population-based AIF from prior study^[3] while RRM and CRRM used muscle as a surrogate for the AIF.

Fitting: Each model fitted voxel-wise over entire prostate. Median value in tumor was compared between visits.

Metrics: Median values were used to calculate CCC and RC%

- CCC = Concordance Correlation Coefficient
Higher is better
- RC% = Percentage Repeatability Coefficient
equal to $2.77 \times wCV \times 100$
Lower is better
- wCV = within-subject coefficient of variation



Discussion

RRM had poorest repeatability for k_{ep} and v_e , but this substantially improved with the CRRM.

Most models had similar RC% for K^{trans} , consistent with prior study^[4]

For Tofts model, population-AIF had better repeatability than measured-AIF for K^{trans} and v_e but slightly poorer for k_{ep} , consistent with prior study^[3]

Conclusion

CRRM can improve the repeatability for k_{ep} and v_e while repeatability for K^{trans} was similar to other models.

Data & Code Availability

Data:
QIN-Prostate-Repeatability is available on The Cancer Imaging Archive [2]

Code:
codeberg.org/notzaki/RRM_Repeatability.jl

References

[1] Ahmed & Levesque. (2017) Increased robustness in reference region model analysis of DCE MRI using two-step constrained approaches. Magn Reson Med. DOI: 10.1002/mrm.26530.

[2] Fedorov et al. (2018). Data From QIN-PROSTATE-Repeatability. The Cancer Imaging Archive.10.7937/K9/TCIA.2018.MR1CKGND

[3] Peled et al. (2019) Selection of Fitting Model and Arterial Input Function for Repeatability in Dynamic Contrast-Enhanced Prostate MRI. Acad Radiol. DOI: 10.1016/j.acra.2018.10.018

[4] Jones et al. (2018). Linearization improves the repeatability of quantitative dynamic contrast-enhanced MRI.Magn Reson Imaging. DOI: 10.1016/j.mri.2017.11.002.