(Quantitative) Imaging for Adaptive Radiotherapy

Catherine Coolens, PhD CIPEM

Department of Medical Physics, Princess Margaret Cancer Centre, Toronto
Department of Radiation Oncology, University of Toronto
Institute of Biomaterials and Biomedical Engineering, University of Toronto
Joint Department of Medical Imaging, University of Toronto
Adjunct Faculty, Techna Institute, Toronto

UHN Toronto General Toronto Western Princess Margaret Toronto Rehab

UNIVERSITY OF TORONTO

TECHNA

Disclosure: No Conflict, No Interest

- Modus Medical Devices Inc.
- Shelley Medical Imaging Technologies

Understanding Imaging: Overview

- Adaptive Imaging Specifications
- Functional Imaging Techniques
- Validation and Standardization

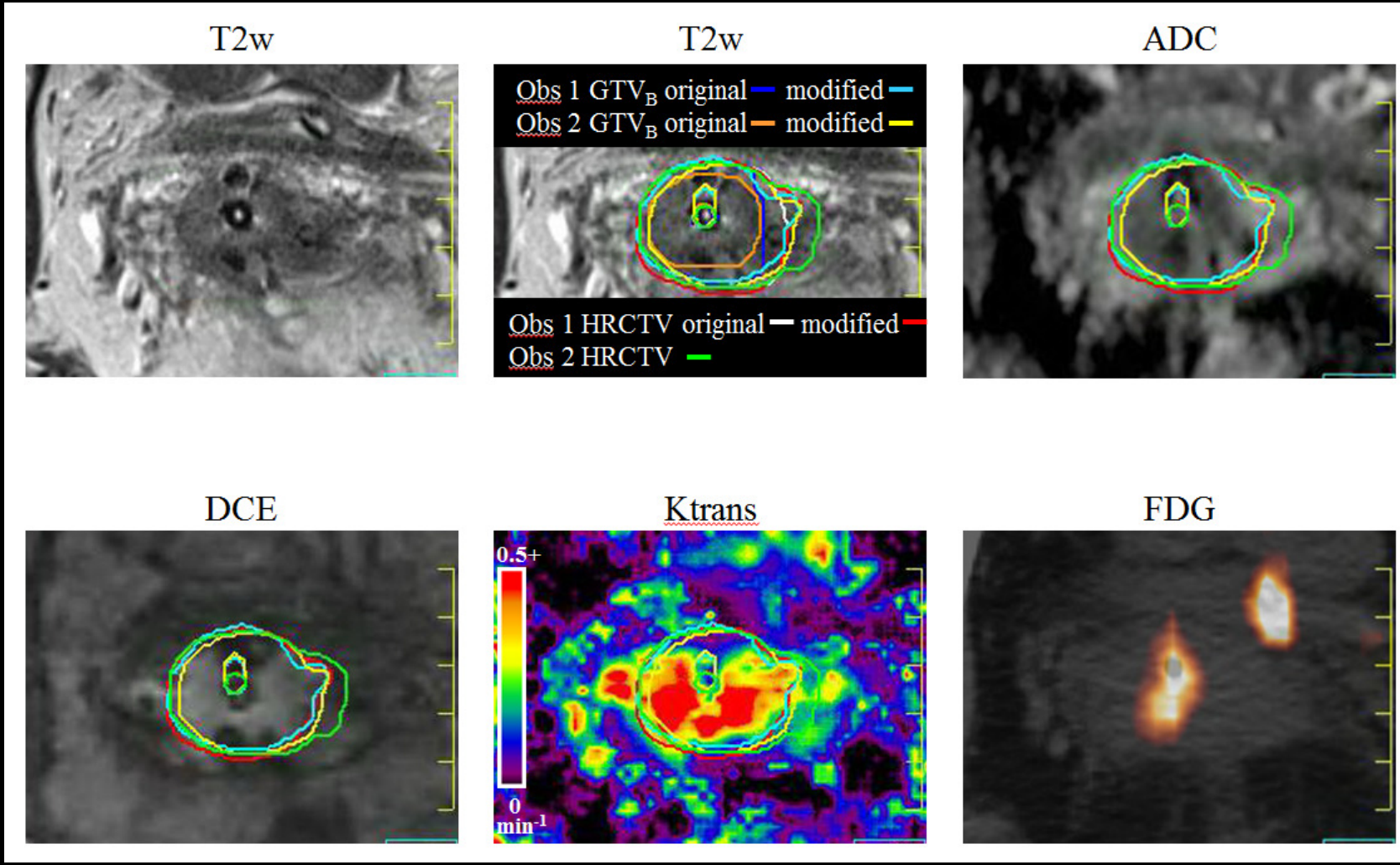
Imaging and Personalized Cancer Medicine

- Quantify individual tumor microenvironment
- Earlier physiological effect than volume change
- Response Assessment to adapt treatment where needed

How interrogate the morphological and physiological status of the tumor before, during and after treatment?

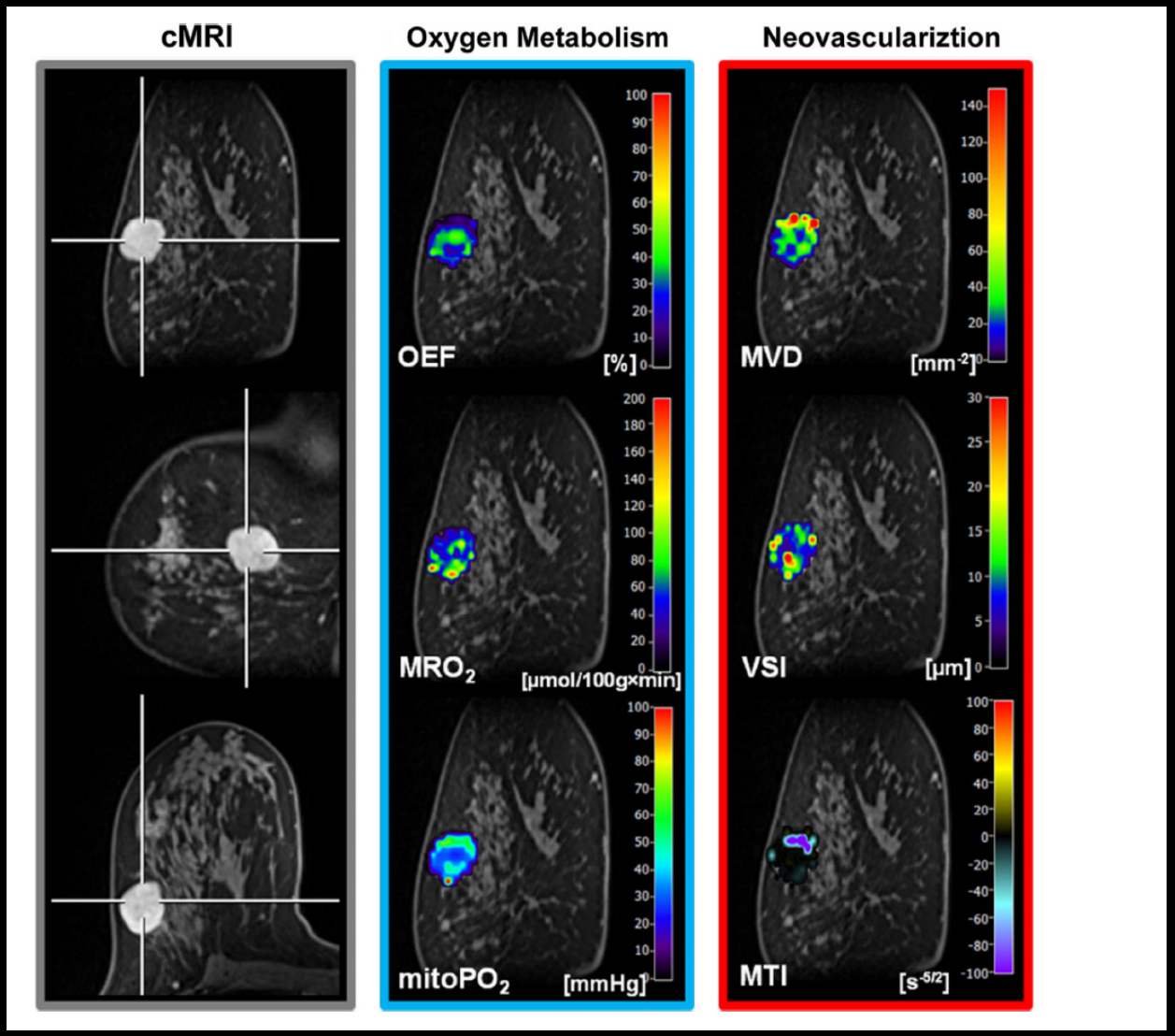
1. Understanding Cancer: Target Definition

Reduced variation in delineation



Han et al. Radiotherapy and Oncology 120 (2016) 519–525

1. Understanding Cancer: Heterogeneity

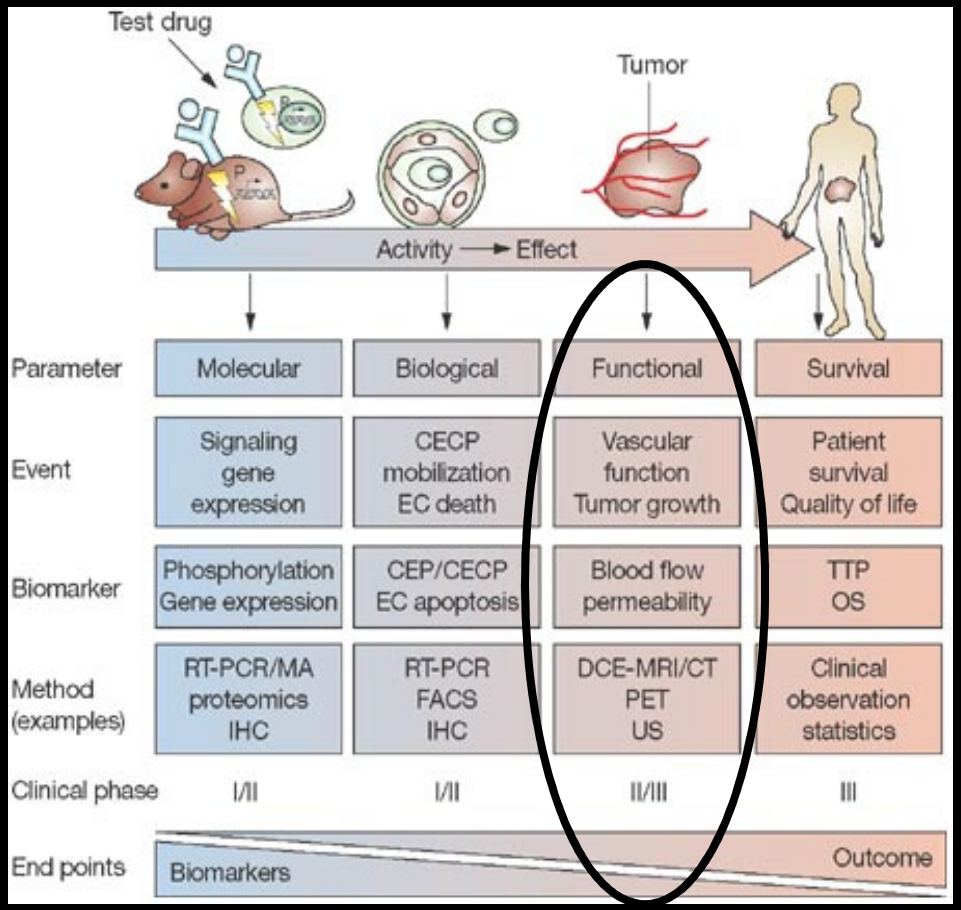


Surrogate prognostic factor

UHN Princess Margaret Cancer Centre

Stadlbauer *et al*. Mol. Imaging Biology 120 (2019) Vol 21(4) 758–770

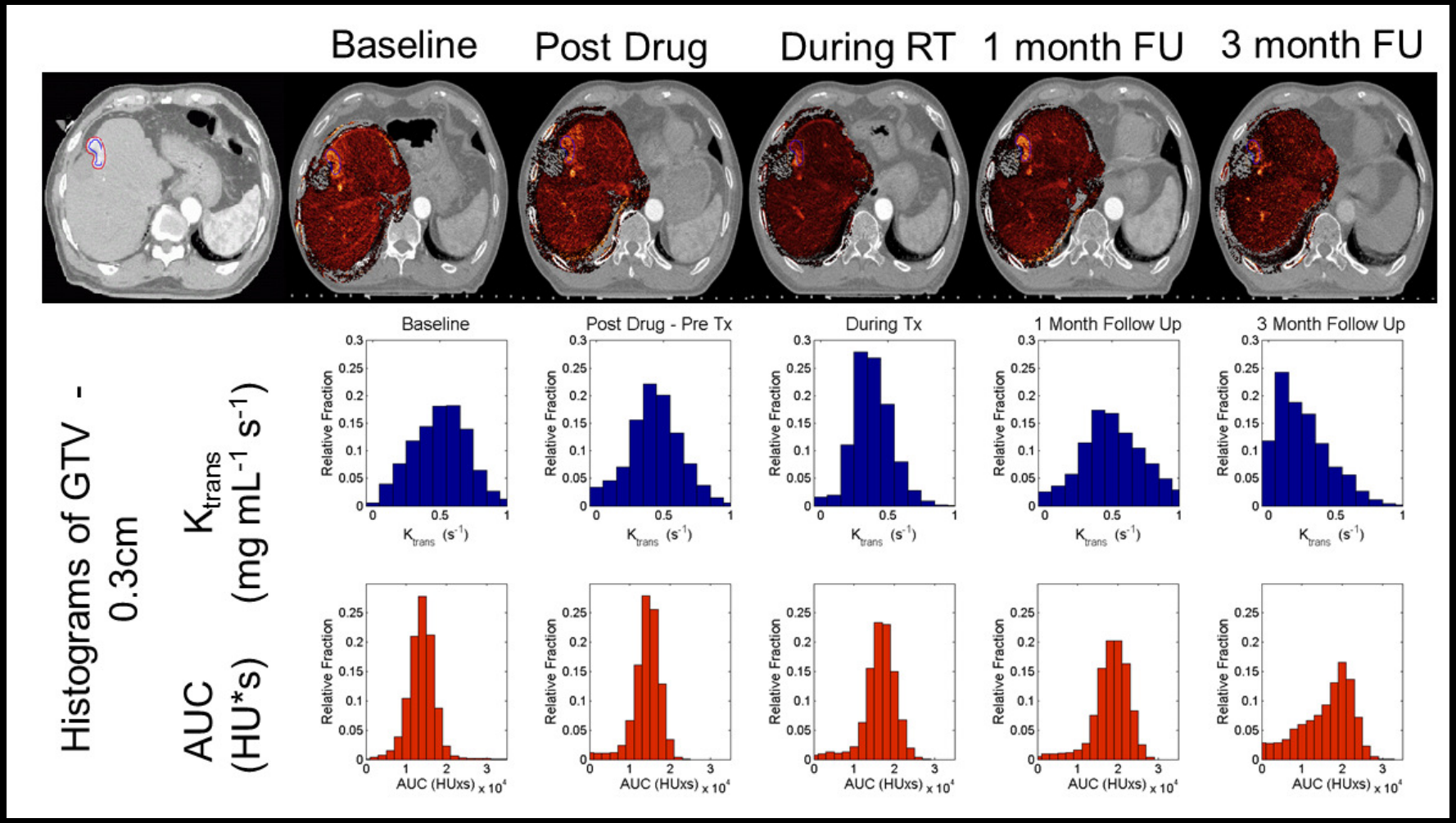
1. Understanding Cancer: Microenvironment



Source: Nat Clin Pract Oncol

- Angiogenesis
- Interstitial Fluid Pressure
- Metabolism
- Oxygenation/Hypoxia
- Cell density
- Vessel Permeability

1. Understanding Cancer: Response



Only histogram moments analysis of parametric maps prognostic

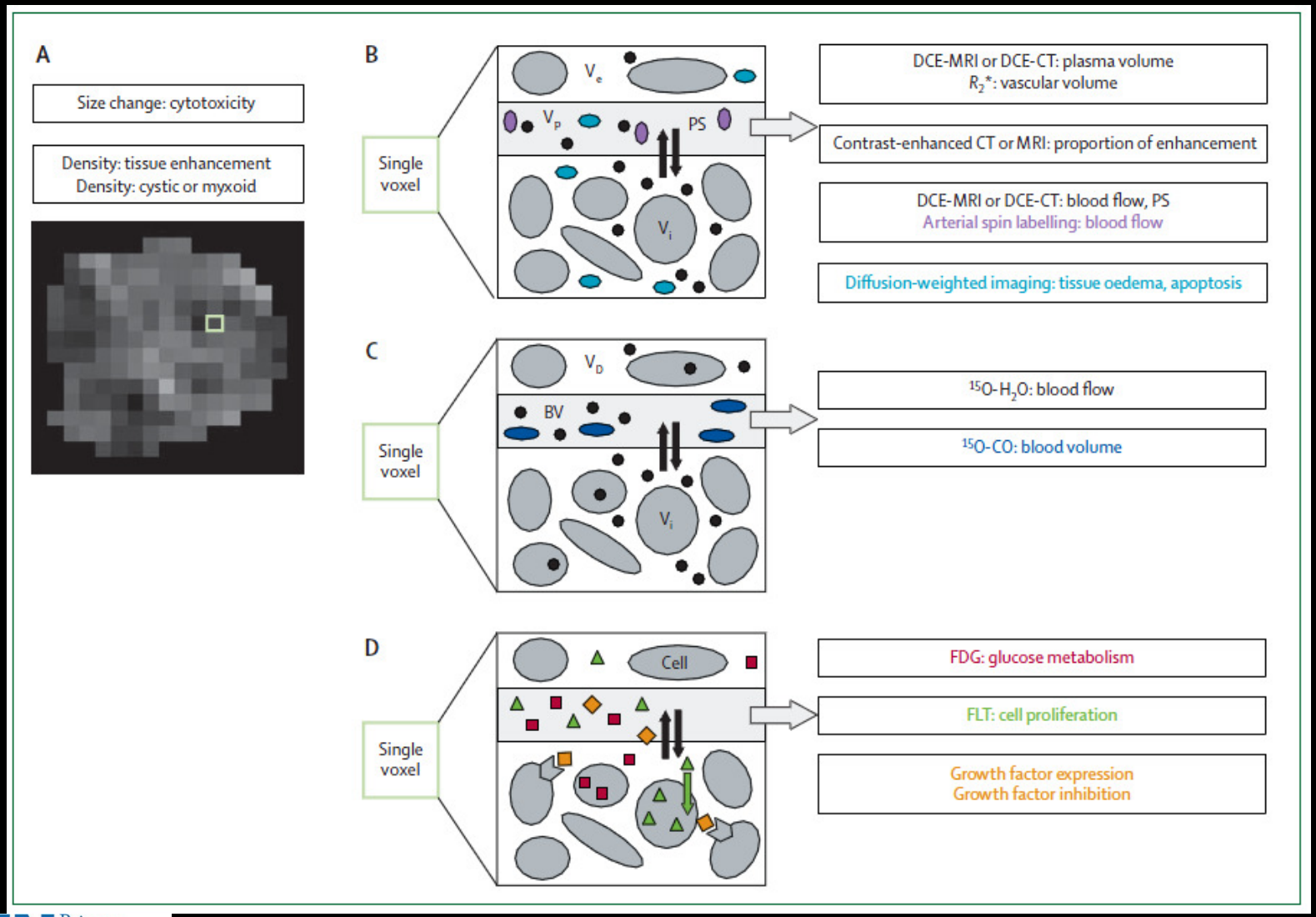
UHN Princess Margaret Cancer Centre

Coolens *et al*. Adv Radiat Oncol. 2016 Jul 1;1(3):194-203.

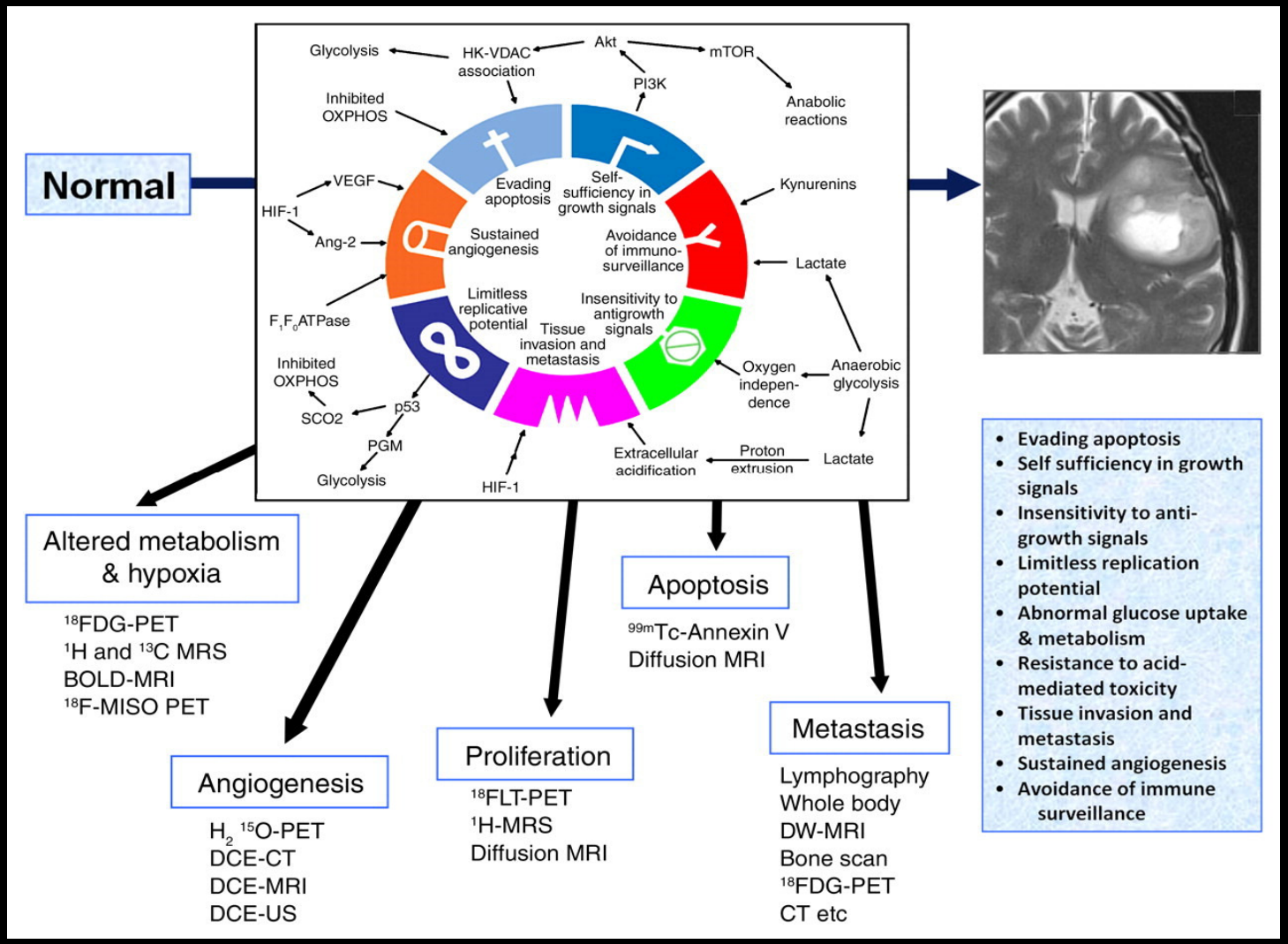
2. Functional Imaging: Requirements

- High spatial resolution
- High temporal resolution
- Clinical convenience
- Non-invasive (single or no bolus)
- (Direct) Quantification
- Biologically relevant surrogate
- Meaningful parametric model

2. Functional Imaging: Overview

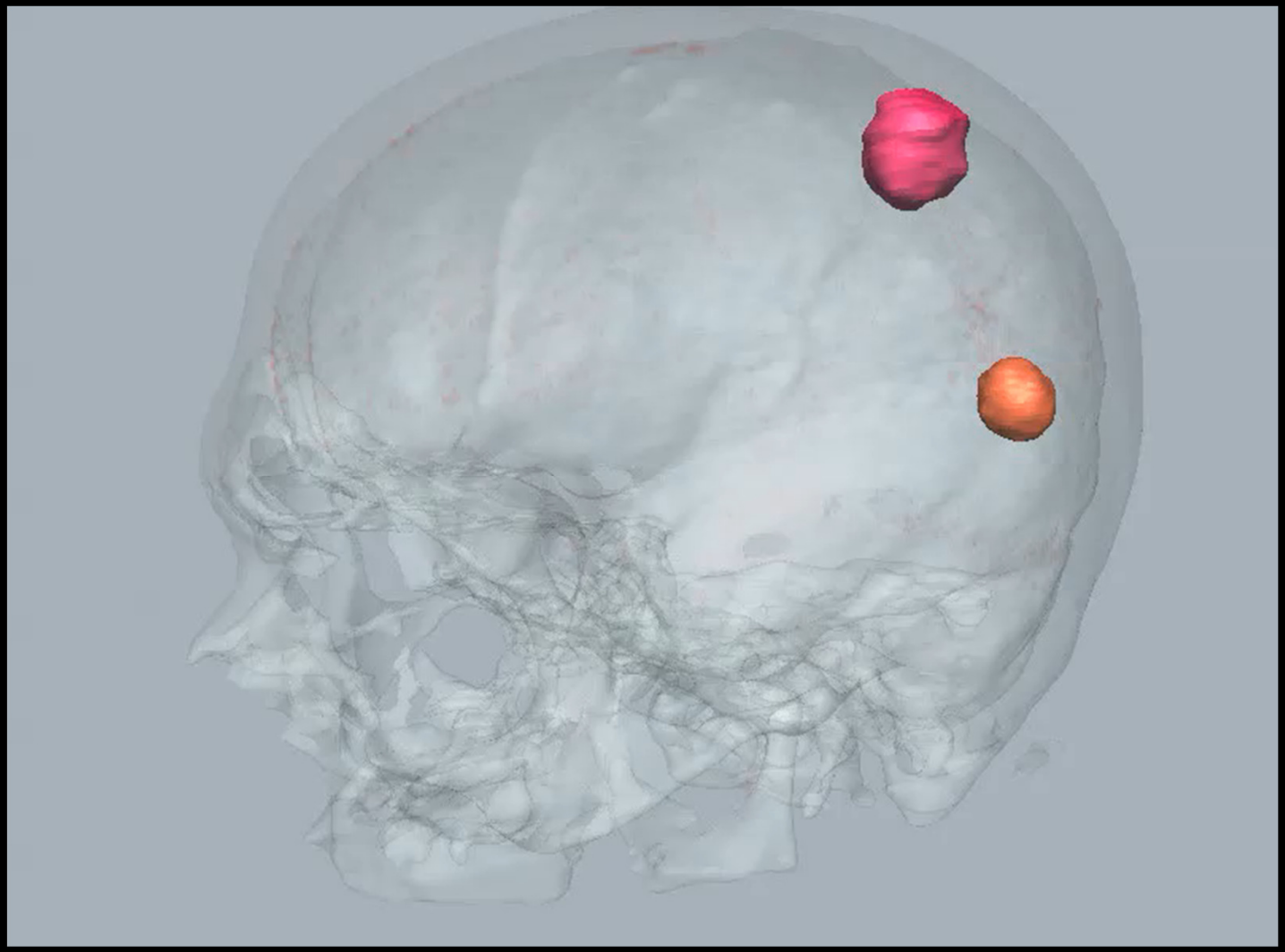


2. Frontiers: Multi-modal Imaging

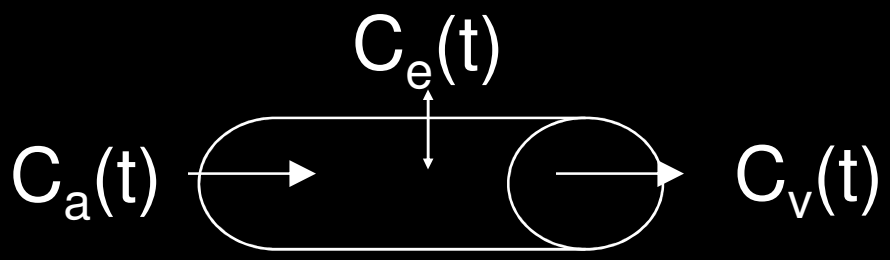


Padhani &Miles, Radiology 2010

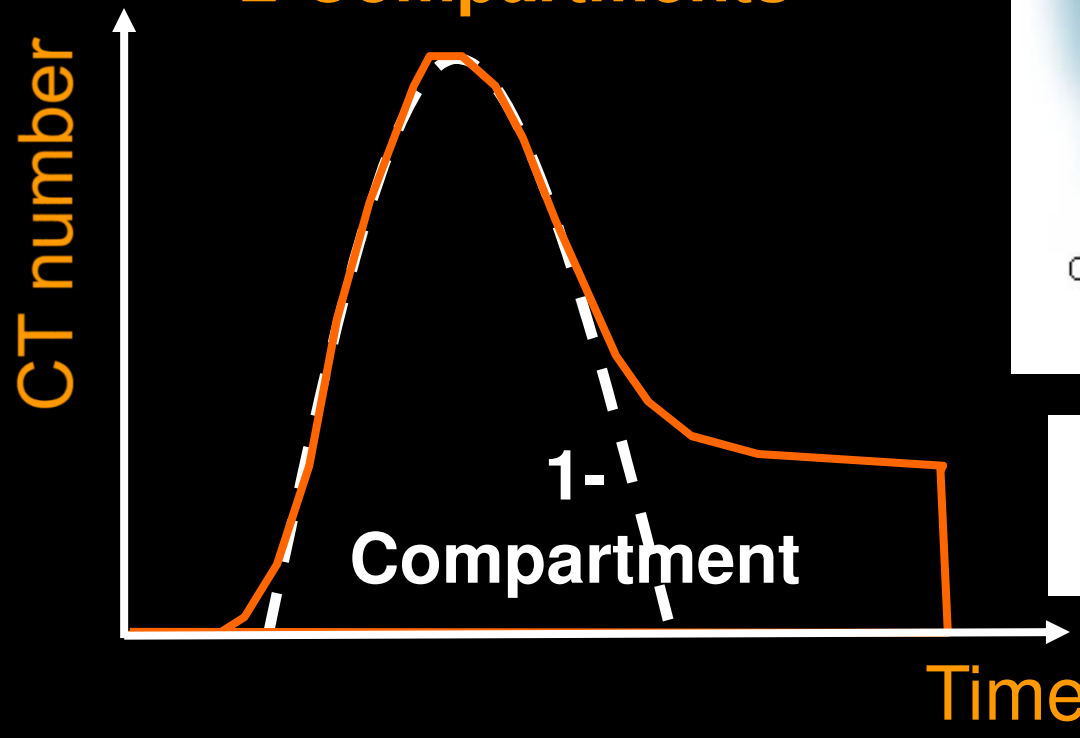
2. Functional Imaging: DCE Imaging

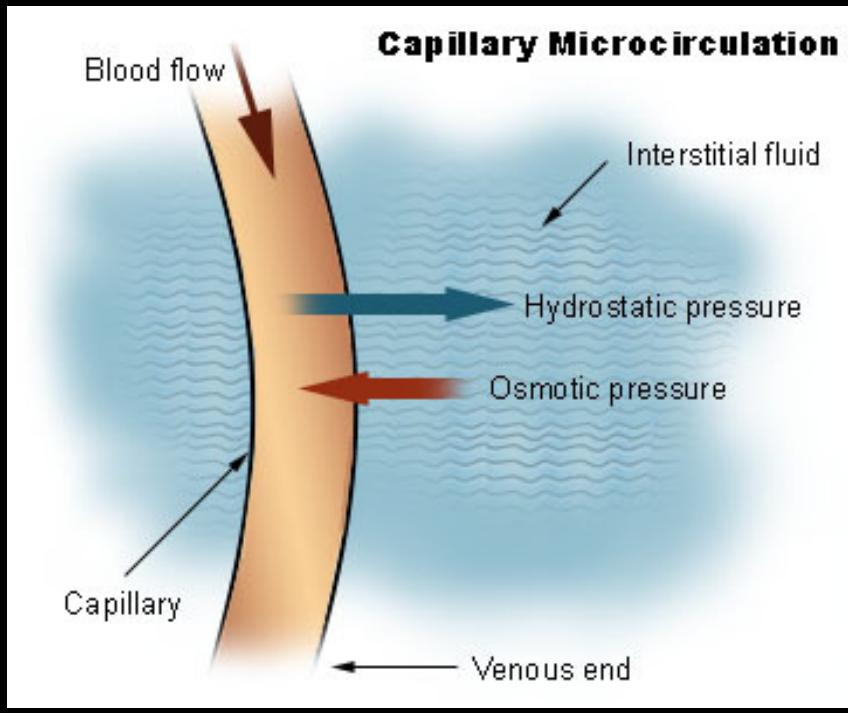


2. Functional Imaging: Kinetic modeling



2-Compartments



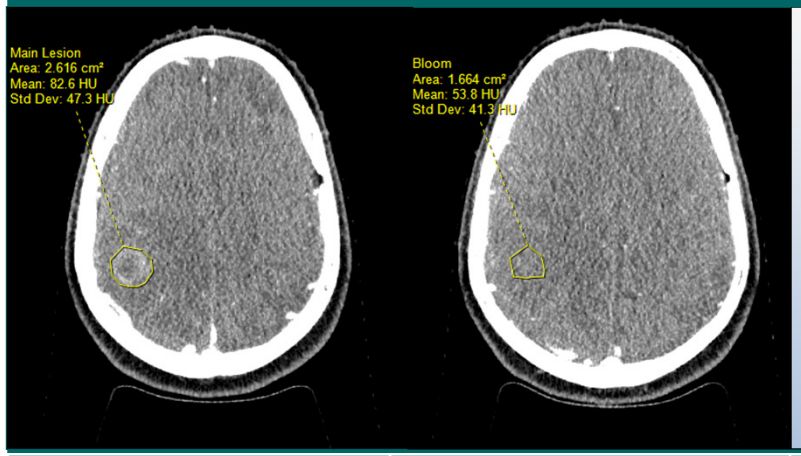


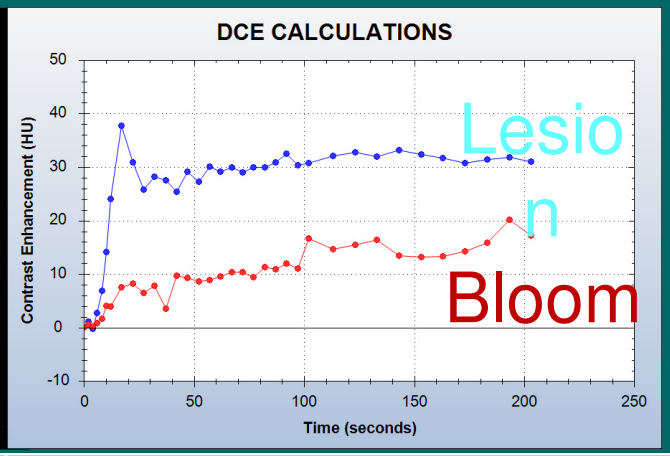
$$C_{tiss}(t) = \frac{\rho F}{1 - Hct} \int_0^t C_a(t - \tau)\, R(\tau) d\tau,$$

Tofts et al 1999 JMRI

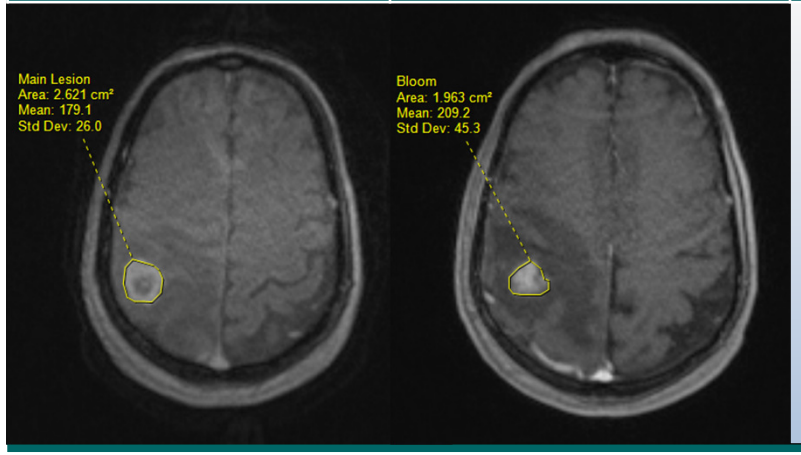
2. DCE Imaging: Iodine vs Gd-DTPA

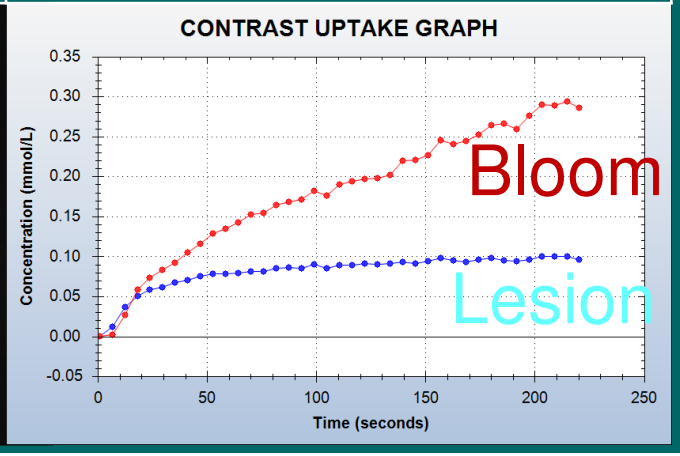
- Main Lesion has stayed roughly the same volume
- Contrast Bloom evident in MR but not CT





Lesion | Contrast Bloom | Time Enhancement Curve





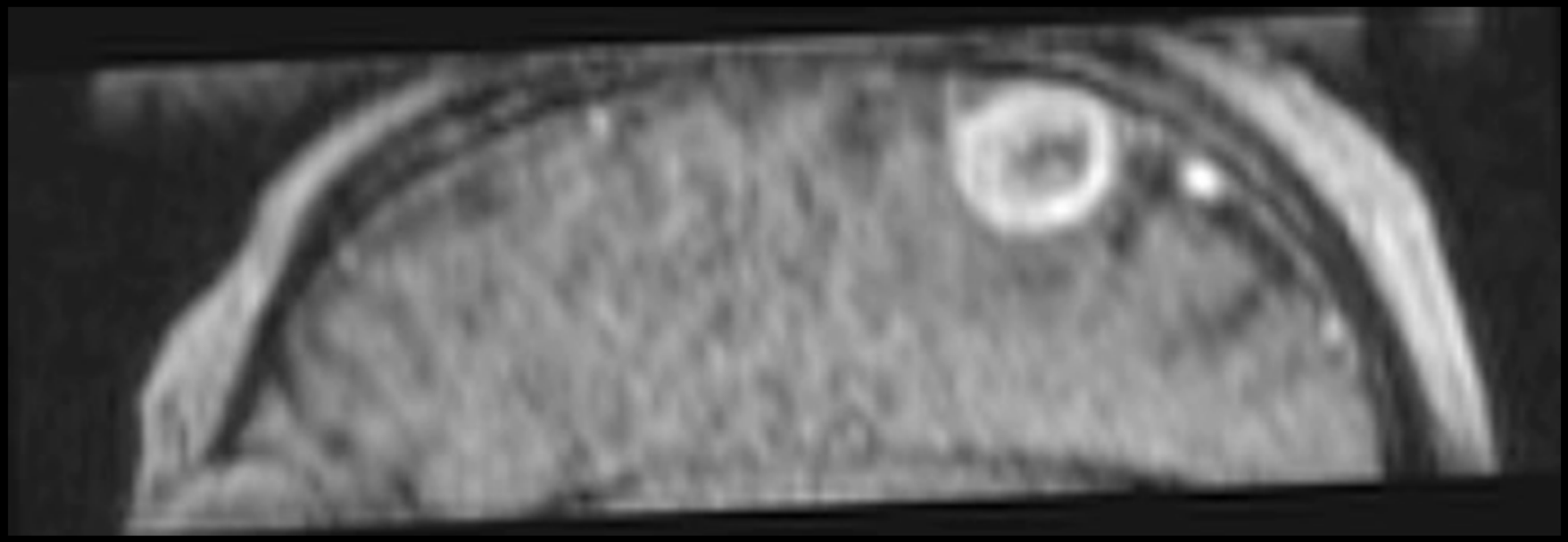
Visipaque

- 320 mgI/mL
- MW **1550.2**

Gadovist

- 1.0 mmol Gd/mL
- MW **604.7**

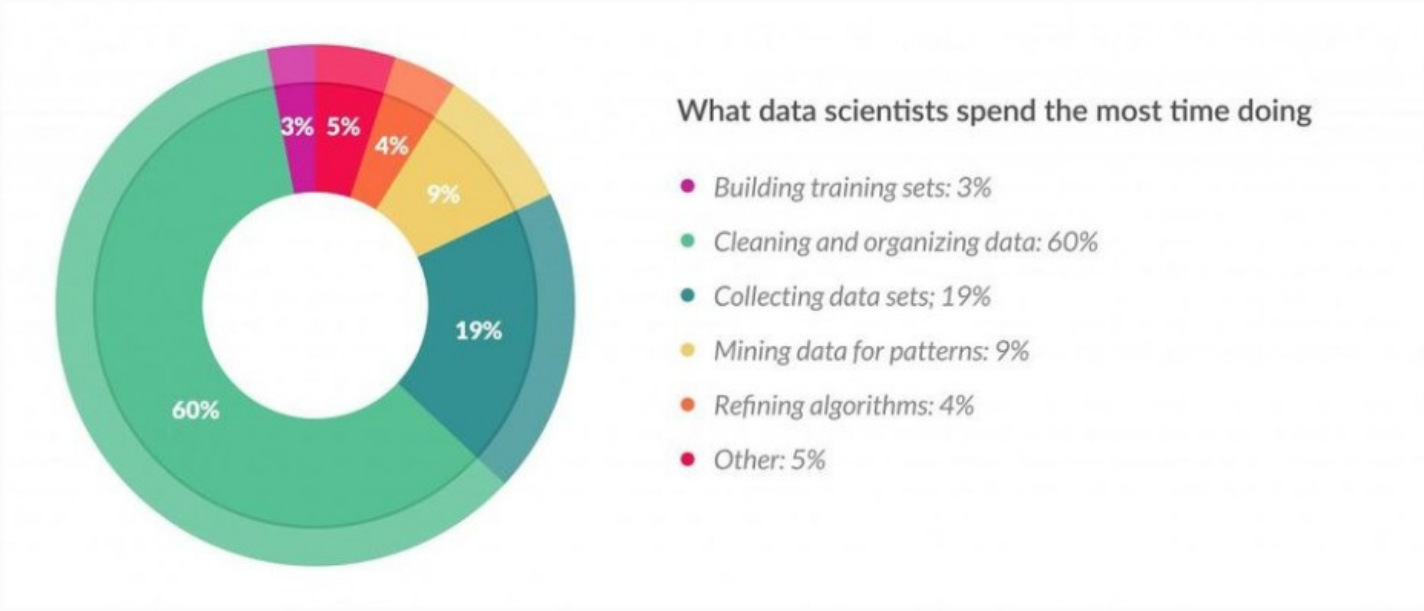
2. Functional Imaging: Transport Flow



Case Study (DCE-MRI) courtesy of T. Hompland

III. Robustness and Standardization

Data preparation *accounts for about 80% of the work of data scientists*



Data scientists spend 60% of their time on cleaning and organizing data. Collecting data sets comes second at 19% of their time, meaning data scientists spend around 80% of their time on preparing and managing data for analysis.

Functional Imaging Validation Framework

- Standardization of image acquisition and analysis
- Correlation with outcome
- Correlation with pathology or tissue biomarkers
- Unified Transport modeling

UHN Princess Margaret Cancer Centre

MULT-SITE DCE CHALLENGE: A CLUSTER FAILURE

SCIENTIFIC REPORTS

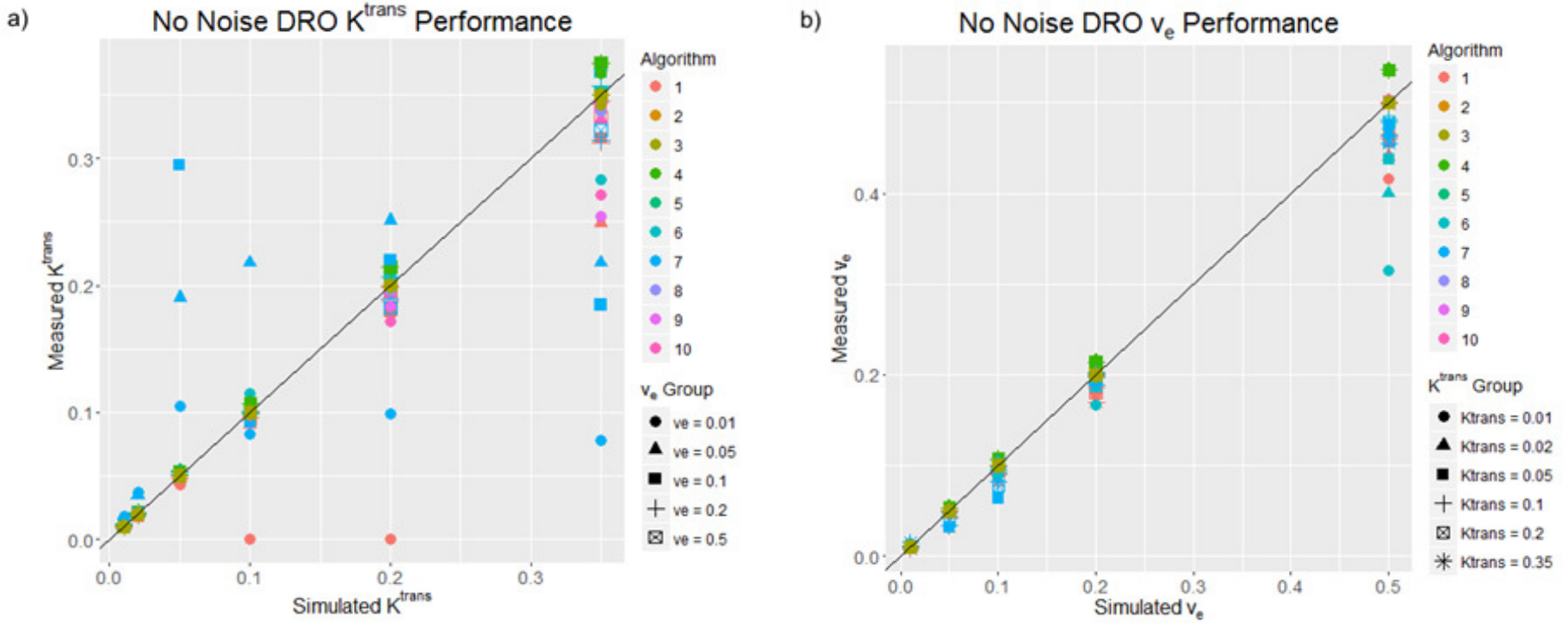
OPEN

l: 5 May 2017
l: 18 August 2017

A Multi-Institutional Comparison of Dynamic Contrast-Enhanced Magnetic Resonance Imaging Parameter Calculations

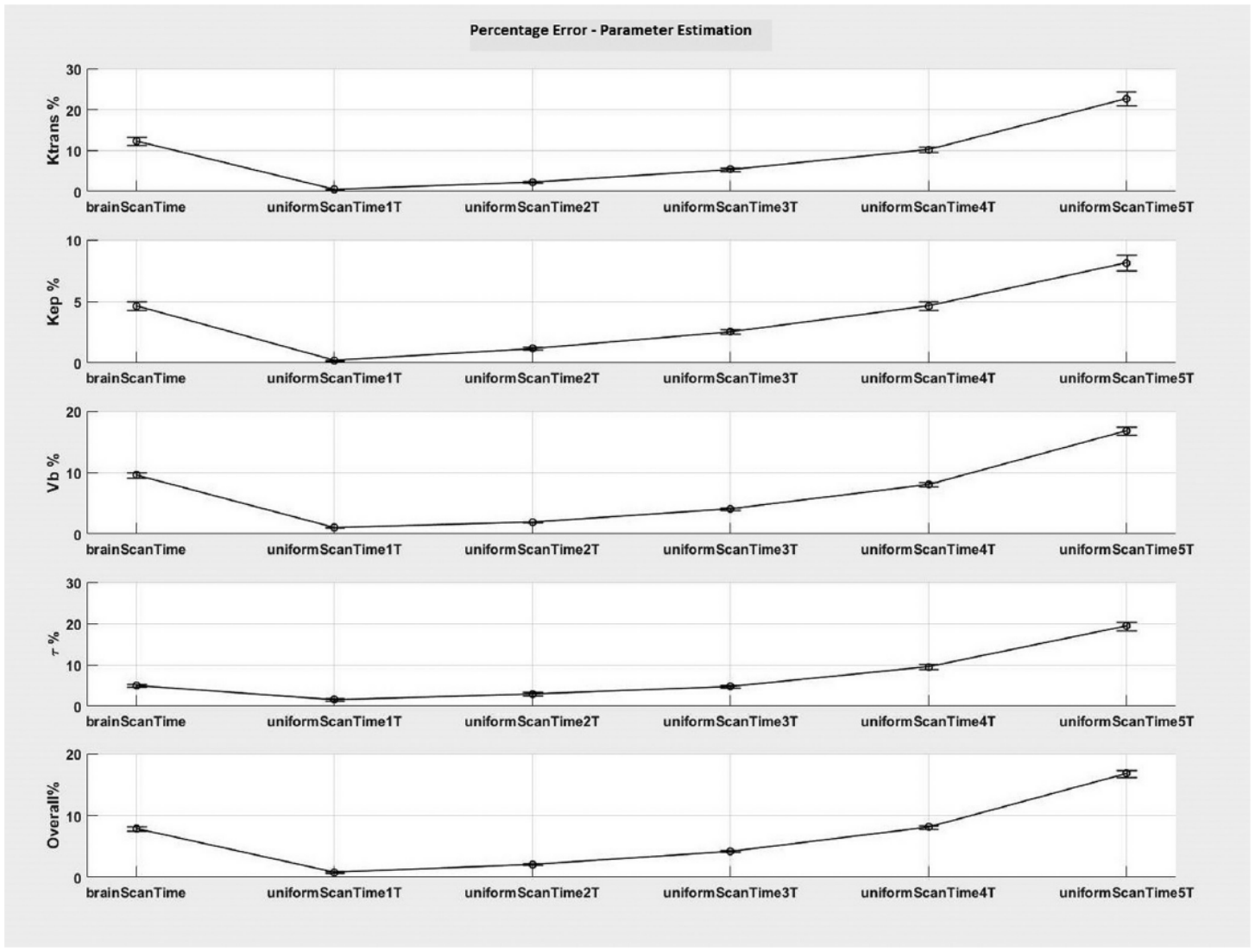
Rachel B. Ger[1,2], Abdallah S. R. Mohamed[3,4], Musaddiq J. Awan[5,6], Yao Ding[7], Kimberly Li[8,9], Xenia J. Fave[1,2], Andrew L. Beers[10], Brandon Driscoll[11], Hesham Elhalawani[3], David A. Hormuth II[12], Petra J. van Houdt[13], Renjie He[14], Shouhao Zhou[15], Kelsey B. Mathieu[7], Heng Li[1,2], Catherine Coolens[11,16,17], Caroline Chung[3,11], James A. Bankson[2,7], Wei Huang[8], Jihong Wang[1,2], Vlad C. Sandulache[18], Stephen Y. Lai[19,20], Rebecca M. Howell[1,2], R. Jason Stafford[2,7], Thomas E. Yankeelov[12], Uulke A. van der Heide[13], Steven J. Frank[3], Daniel P. Barboriak[21], John D. Hazle[2,7], Laurence E. Court[1,2,7], Jayashree Kalpathy-Cramer[10] & Clifton D. Fuller[2,3]

Variation in modeling implementation



Ger et al. 2017. A Multi-Institutional Comparison of Dynamic Contrast-Enhanced Magnetic Resonance Imaging Parameter Calculations. *Scientific Reports*, *7*(1), [11185]

Parametric Sensitivity to Acquisition

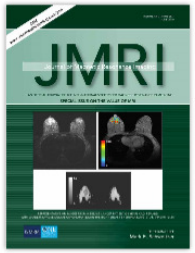


Svistoun *et al*. QIN Special Issue. Tomography 5(1), 209-219, 2019.

DCE and DWI Imaging Validation

JMRI Journal of Magnetic Resonance Imaging

ISMRM ONE COMMUNITY FOR CLINICIANS AND SCIENTISTS



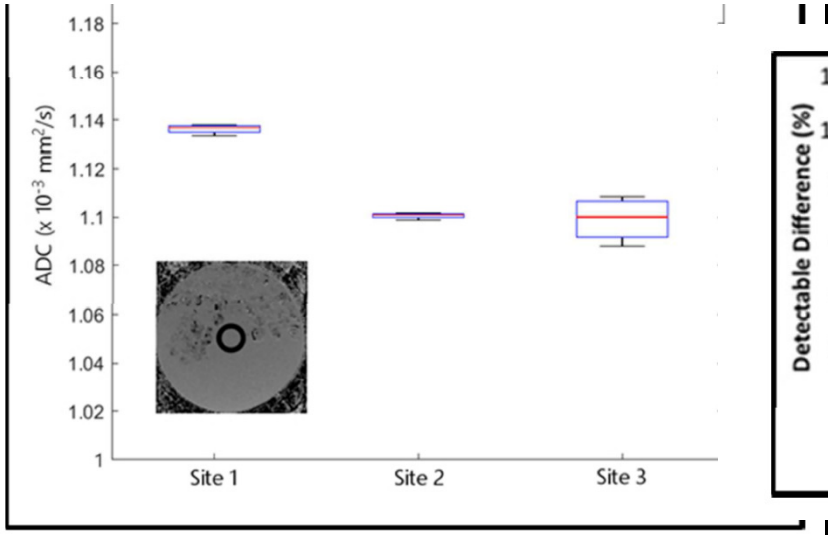
Volume 49, Issue 7
Special Issue: Special Issue on the Value of MRI
June 2019
Pages e101-e121

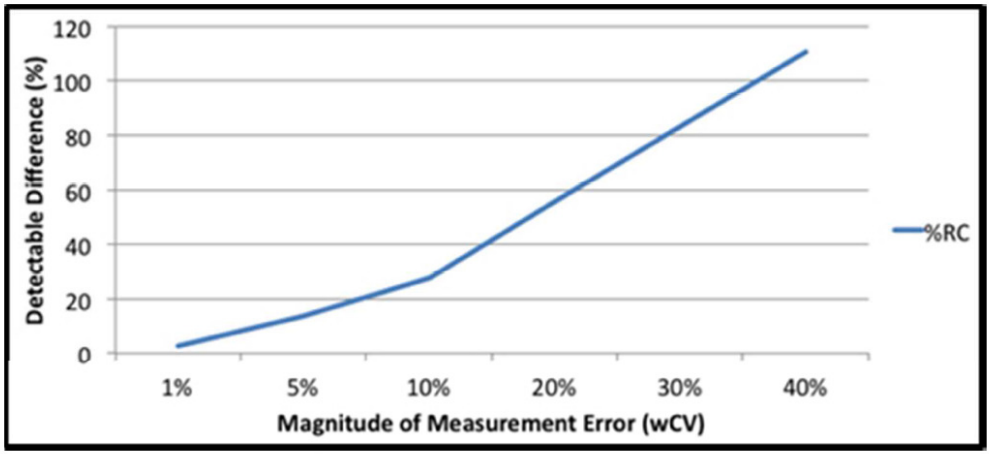
Review Article

Quantitative imaging biomarkers alliance (QIBA) recommendations improved precision of DWI and DCE-MRI derived biomarkers in multicenter oncology trials

Amita Shukla-Dave PhD, Nancy A. Obuchowski PhD, Thomas L. Chenevert PhD, Sachin Jambawalikar PhD, Lawrence H. Schwartz MD, Dariya Malyarenko PhD, Wei Huang PhD ... See all authors

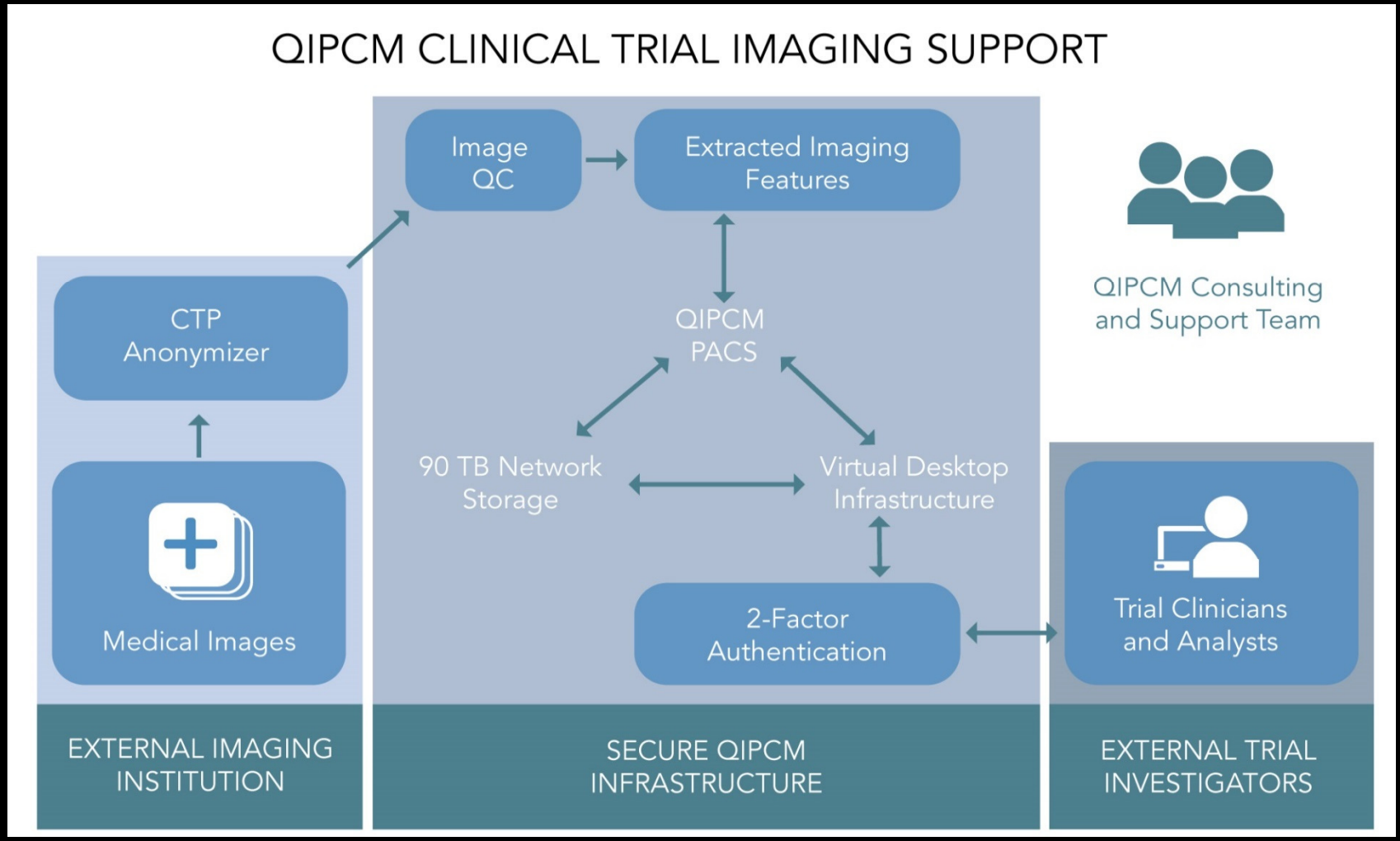
First published 19 November 2018 | https://doi.org/10.1002/jmri.26518 | Cited by: 5





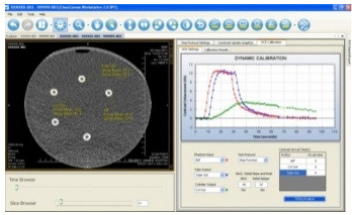
UHN Princess Margaret Cancer Centre

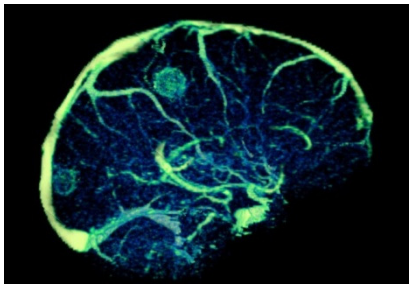
Imaging Core Lab: Imaging Trial Support

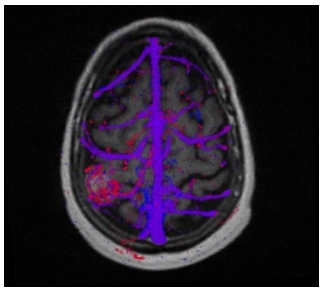


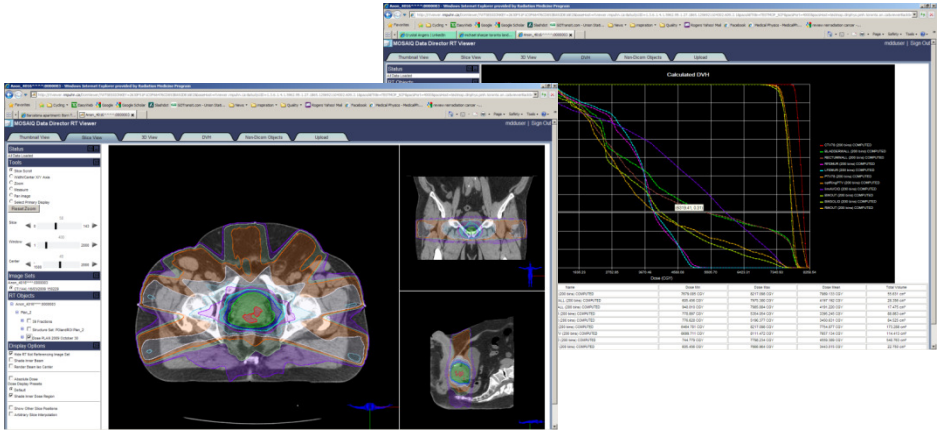
https://technainstitute.com/qipcm/

QIPCM: Standardized Tools









The DCE QA Tool

- Using a validated dynamic flow phantom perform DCE QA for any CT scanner.

4D TDA CT/MRI

- A robust method for automatic 3D vasculature segmentation and unified parametric voxel-based analysis of DCE CT & DCE-MR, DWI scans without the need for manual tissue ROI delineation.

Web Based RT Viewer

- Browser-based RT-specific viewer for visualization, review and workflow (automated navigation and quality assurance tools)

Standards & Guidelines: RSNA

- Quantitative Imaging Biomarker Alliance (QIBA)

QIBA organization

QIBA has advanced through the generous commitment of volunteer committee members from academia, medical device, pharmaceutical and other business sectors and government.

There are four modality-based Coordinating Committees, including Q-CT, Q-MR, Q-NM and Q-US. Nineteen Biomarker Committees include:

- CT
  - CT Angiography
  - CT Volumetry
  - Lung Density
  - Small Lung Nodule
- MR
  - Arterial Spin Labeling (ASL)
  - Dynamic Contrast-Enhanced (DCE) MRI
  - Dynamic Susceptibility Contrast (DSC) MRI
  - Diffusion Weighted Imaging (DWI) MRI
  - Functional Magnetic Resonance Imaging (fMRI)
  - Magnetic Resonance Elastography (MRE)
  - Proton Density Fat Fraction (PDFF)
  - Musculoskeletal (MSK)
- NM
  - FDG-PET/CT
  - Quantifying Dopamine Transporters with 123Iodine Labeled Ioflupane in Neurodegenerative Diseases (I-123)
  - PET-Amyloid
  - Technetium-99m for body, oncology and immunology (TC99m)
- US
  - Contrast Enhanced Ultrasound (CEUS)
  - Ultrasound Shear Wave Speed (SWS)
  - Ultrasound Volume Blood Flow (VBF)

Each committee has specific responsibilities for its respective modalities or disease-based approach, and is open to interested persons.

View the QIBA organizational chart.

Standards & Guidelines: NCI

- Quantitative Imaging for Evaluation of Responses to Cancer Therapies (QIN)

NIH NATIONAL CANCER INSTITUTE
DCTD Division of Cancer Treatment & Diagnosis

Home | Sitemap | Contact CIP

Search this site

CIP Cancer Imaging Program

Home | About CIP | Research Funding | Programs & Resources | Clinical Trials | Informatics | News & Events | Imaging Basics

The next QIN Annual Meeting will be held May 4-5, 2020.

- About QIN
  - Background, Mission, and Goal
  - Teams
  - Network Structure
  - Request Application
- QIN Cooperative Agreement
- QIN Activities
- Selected QIN Publications
- Validating QIN Tools
- Special Events
- Contact Us/Staff

Search QIN

Search

Programs & Resources | Quantitative Imaging Network (QIN)

Last Updated: 06/13/19

Quantitative Imaging Network (QIN)

About the Quantitative Imaging Network (QIN)

The Quantitative Imaging Network (QIN) promotes research, development and clinical validation of quantitative imaging tools and methods for the measurement or prediction of tumor response to therapies in clinical trial settings, with the overall goal of facilitating clinical decision making. Projects include the development and adaptation/implementation of quantitative imaging methods, imaging protocols, and software solutions/tools (using existing commercial imaging platforms and instrumentation) and application of these methods in current and planned clinical therapy trials. The research projects focus on image-derived quantitative measurements of responses to drugs and/or radiation therapy during clinical trials or standard of care. To achieve the goals of the QIN, multidisciplinary teams which include oncologists as well as clinical and basic imaging scientists are required. The involvement of industrial partners in the development and adaptation/implementation of quantitative imaging methods to aid cancer therapies are encouraged.

Standards & Guidelines: AAPM

- MRI - Molecular Imaging in

  - TG 294: Magnetic Resonance Biomarkers in Radiation Oncology
  - TG 284: MRI Simulation in Radiotherapy: Considerations for Clinical Implementation, Optimization, and Quality Assurance

Summary

1. Importance of Functional Imaging in Simulation and Treatment Response Assessment

2. Multi-modality Imaging Approach to support complementary Response Assessment describing broader micro-environment

3. Further standardization and validation of functional image acquisition and analysis for clinical trials is needed

Acknowledgements

Techna/QIPCM Team

Medical Physics:
Warren Foltz
Stephen Breen
Jeff Winter
David Jaffray

Radiation Oncology
Cynthia Menard
Caroline Chung
Laura Dawson
Andrew Hope
Mike Milosevic
Kathy Han

Medical Imaging
Narinder Paul
Patrick Rogalla
David Mikulis

Thank You

Questions?

catherine.coolens@uhn.ca

UHN Princess Margaret Cancer Centre

References

- MR & CT Perfusion Imaging: Clinical Applications and Theoretical Principles. Editor: R Bammer. Lippincott Williams & Wilkins 2016. ISBN: 978-1-451-14715-5
- Foltz W et al. Phantom Validation of DCE-MRI Magnitude and Phase-Based Vascular Input Function Measurements. Tomography. 2019 Mar;5(1):77-89
- Svistoun I, Driscoll B, Coolens C. Accuracy and Performance of Functional parameter estimation using a Novel Numerical Optimization Approach for GPU-Based Kinetic Compartmental Modeling. Tomography. 2019 Mar;5(1):209-219
- Coolens C, Driscoll B, Foltz W, Svistoun I, Sinno N, Chung C. Unified platform for multimodal voxel-based analysis to evaluate tumour perfusion and diffusion characteristics before and after radiation treatment evaluated in metastatic brain cancer. Br J Radiol. 2018 Sep 20:20170461.
- Coolens C, Mohseni H, Dhody S, Ma S, Keller H, Jaffray DA. Quantification accuracy for dynamic contrast enhanced (DCE) CT imaging: phantom and quality assurance framework. Eur J Radiol. 2018 Sep;106(2018)
- Han K, Croke J, Metser U, Foltz W, Xie J, Shek T, Driscoll B, Menard C, Vines D, Coolens C, Simeonov A, Beiki-Ardakani A, Leung E, Levin W, Fyles A, Milosevic M F. A Prospective Study of DWI, DCE-MRI and FDG PET Imaging for Target Delineation in Brachytherapy for Cervical Cancer. Radiotherapy and Oncology. 2016. Sep; 120(3):519-525.
- Coolens C, Driscoll B, Moseley K, Brock KK, Dawson LA. Feasibility of 4D perfusion CT imaging for the assessment of liver treatment response following SBRT and sorafenib. Adv Radiat Oncol. 2016 Jul 1;1(3):194-203.
- Coolens C, Driscoll B, Foltz W, Pellow C, Menard C, Chung C. Comparison of Voxel-Wise Tumor Perfusion Changes Measured With Dynamic Contrast-Enhanced (DCE) MRI and Volumetric DCE CT in Patients With Metastatic Brain Cancer Treated with Radiosurgery. Tomography. 2016. Vol 2 (4); 325-333.
- Jaffray D.A., Chung C., Coolens C, Foltz W., Keller H., Menard C., Milosevic M., Publicover J., Yeung I. Quantitative Imaging for Radiation Oncology. Seminars in Radiation Oncology. 2015 Oct;25(4):292-304.
- Coolens C, Driscoll B, Chung C, Gorjizadeh A, Shek T, Menard C, Jaffray DA. Automated Voxel-based Analysis of Volumetric Dynamic-Enhanced CT data improves measurement of serial changes in tumor vascular biomarkers. International Journal of Radiation Oncology Biology Physics. 2015 Jan;91(1):48-57. Available from: DOI: 10.1016/j.ijrobp.2014.09.028.
- Positron Emission Tomography. Basic Sciences. Editors: DL Bailey, DW Townsend, PE Valk, MN Maisey. Springer-Verlag London 2005
- Shukla-Dave A et al. Quantitative imaging biomarkers alliance (QIBA) recommendations for improved precision of DWI and DCE-MRI derived biomarkers in multicenter oncology trials. J Magn Reson Imaging. 2019 Jun;49(7)
- Padhani AR and Miles KA,. Multiparametric Imaging of Tumor Response to Therapy . Radiology, Vol. 256: No 2, 2010.

UHN Princess Margaret Cancer Centre