Session in Memory of Edward F. Jackson:

The Expanding Role of the Physicist in MRI

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The University of Texas MD Anderson Cancer Center

AAPM 2021

July 25–29 | Virtual

63rd Annual Meeting & Exhibition

Creative Science. Advancing Medicine.

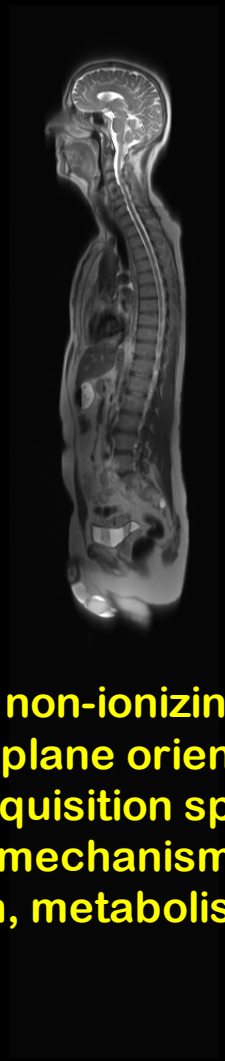
Neuro | Abdominal | Breast | MSK | Thoracic

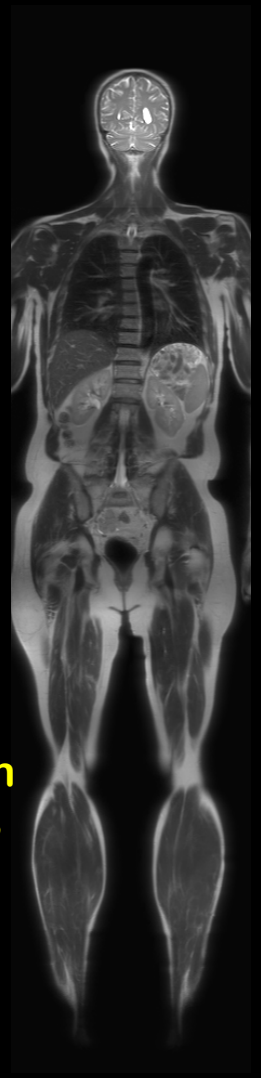
Anatomic

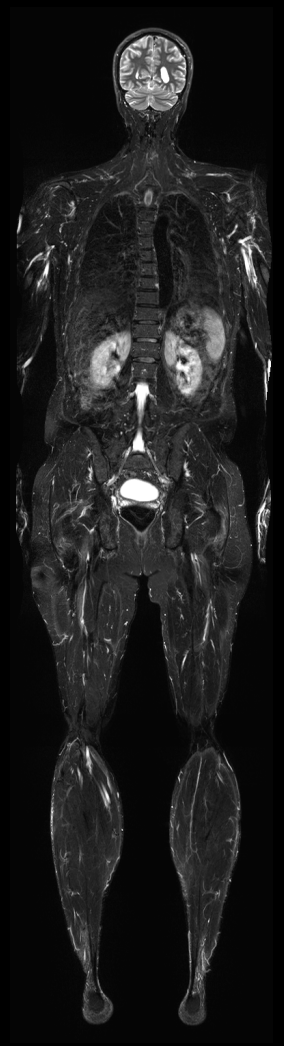
Vascular & Flow

Physiology & Function

Molecular/ Metabolism







- Non-invasive and non-ionizing
- Arbitrary oblique plane orientation
- Near real-time acquisition speeds
- Multiple contrast mechanisms for anatomy, function, metabolism

T1-weighted

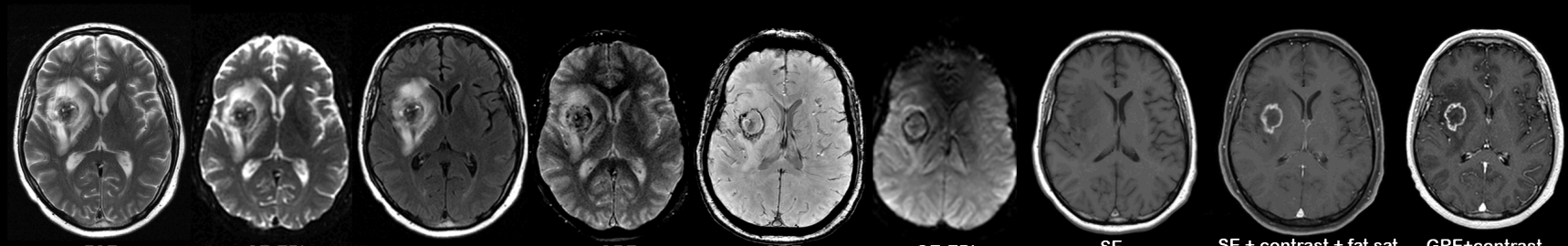
T2-weighted

T2-weighted FS

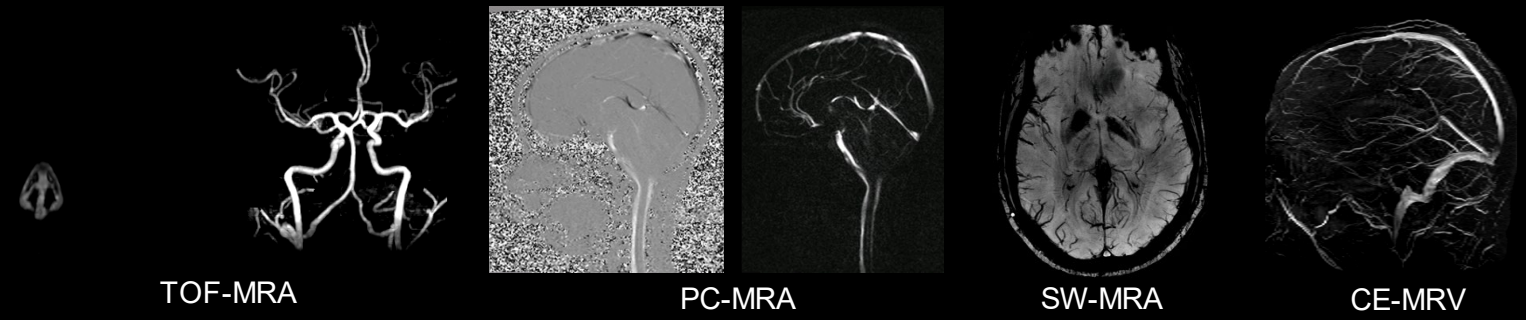
Diffusion-weighted

Neuro | Abdominal | Breast | MSK | Thoracic

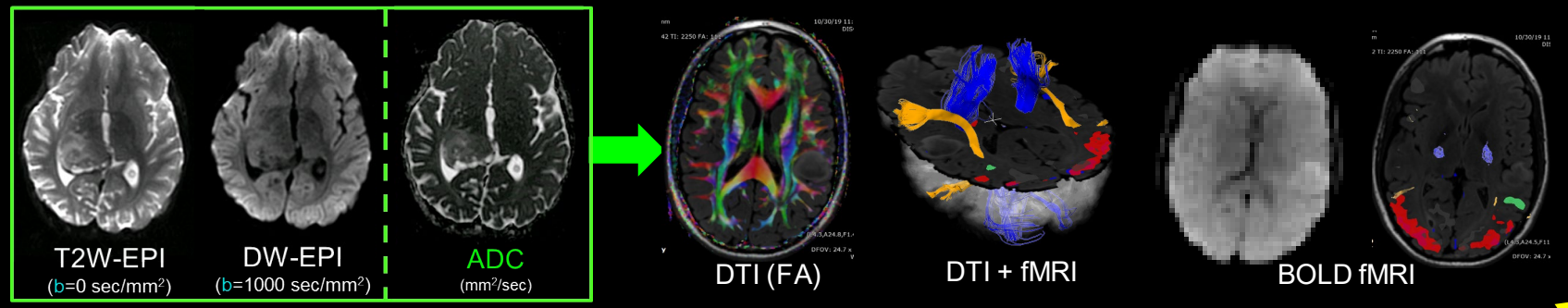
Anatomic



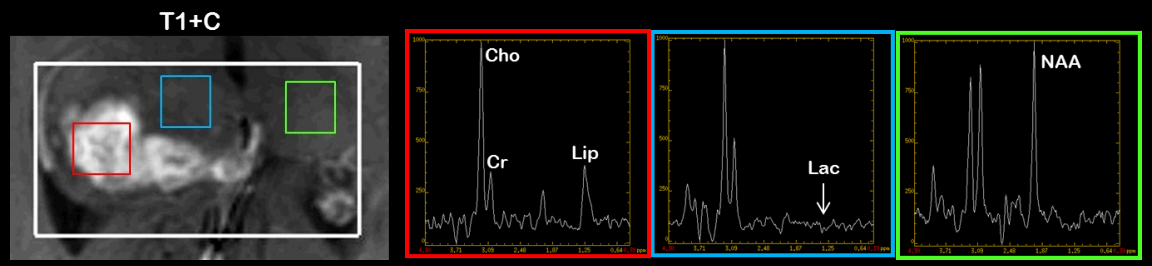
Vascular & Flow



Physiology & Function

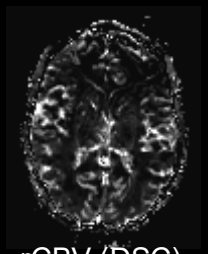


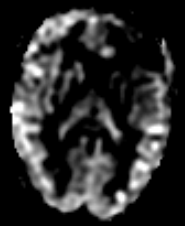
Molecular/ Metabolism

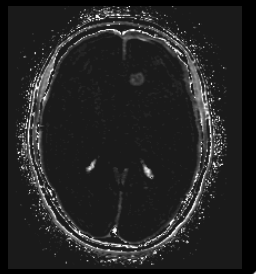


Observing contrast flow into tissue facilitates ability to infer much more than anatomy and vasculature


CE T1W

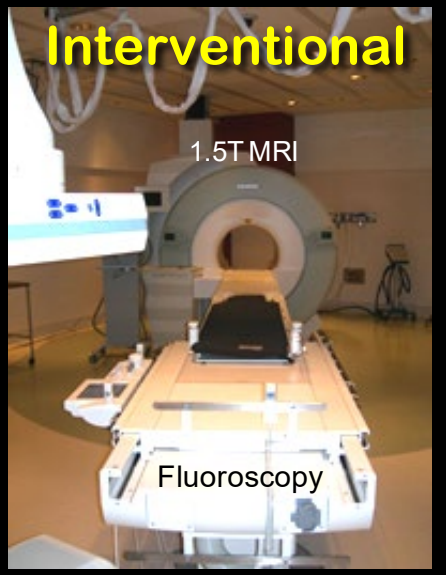

rCBV (DSC)

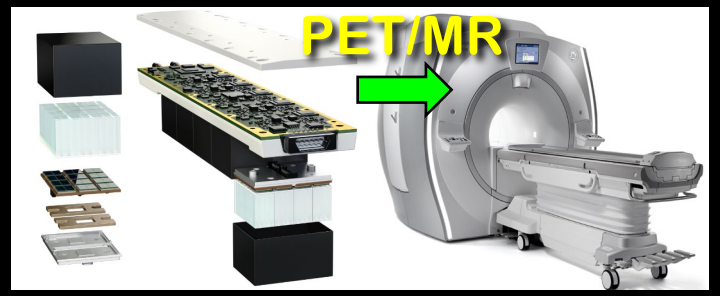

rCBF (ASL)


Ktrans (DCE)

Advances and challenges in MRI

- Acquisition & reconstruction hardware/software
- Pulse sequence advances
  - Contrast & Speed
- Rapid and continuous growth in applications
  - diagnostic indications
  - hybrid MR suites
  - functional imaging
- Drive toward higher reliability & image quality





From Science to Practice: Consensus, Guidance & Education

MAGNETIC RESONANCE IMAGING ACR AMERICAN COLLEGE OF RADIOLOGY ACCREDITED FACILITY

ACR Manual on MR Safety

Version 1.0

2020

ACR Committee on MR Safety

ACR AMERICAN COLLEGE OF RADIOLOGY QUALITY IS OUR IMAGE

AAPM REPORT NO. 100

Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities

Report of MR Subcommittee Task Group 1

December 2010

AAPM REPORT NO. 197
(Revision of AAPM Report No. 79)

Academic Program Recommendations for Graduate Degrees in Medical Physics

Report of the Education and Training of Medical Physicists Committee

April 2009

The Joint Commission

• Issued August 10, 2015 •

Diagnostic Imaging Requirements

Scientific & Professional Societies

AMERICAN ASSOCIATION of PHYSICISTS IN MEDICINE

ACR AMERICAN COLLEGE OF RADIOLOGY

ISMRM ONE COMMUNITY FOR CLINICIANS AND SCIENTISTS

RSNA

AAPM REPORTS & DOCUMENTS

WILEY

AAPM medical physics practice guideline 10.a.: Scope of practice for clinical medical physics

For the purpose of providing clinical professional services, a Qualified Medical Physicist (QMP) is an individual who is competent to independently provide clinical professional services in one or more of the subfields* of medical physics. A QMP is qualified to practice only in the subfield(s) in which they are certified. The subfields of medical physics are:

1. Therapeutic Medical Physics
2. Diagnostic Medical Physics
3. Nuclear Medical Physics
4. Medical Health Physics
5. Magnetic Resonance Imaging Physics

For the subfield of Magnetic Resonance Imaging Physics, certification by:

- The American Board of Radiology, Diagnostic Medical Physics; or
- The American Board of Medical Physics, Magnetic Resonance Imaging Physics.
- The Canadian College of Physicists in Medicine, Magnetic Resonance Imaging Physics.

WHAT DOES A CLINICAL MRI PHYSICIST DO?

MRI Equipment Quality Management

MRI physicists design and oversee quality assurance programs, which track system performance to ensure safe, high quality patient care. They also ensure that accreditation and clinical trial performance criteria are met. The continual development of new MRI technologies makes their role both challenging and rewarding. With their extensive knowledge of MRI equipment and software, physicists are deeply involved in equipment specification and siting processes. This is particularly true for the growing number of hybrid MRI suites, which require consideration of many additional factors that greatly increase installation complexity.

Image Quality Management

MRI physicists are indispensable members of the quality management team. An essential part of their role is to ensure that the image data provide reliable diagnostic information for use in patient management decisions. Physicists also work closely with equipment manufacturers to make sure that image quality concerns are promptly resolved. Their expertise is required to develop and optimize exam protocols and to facilitate protocol standardization across multiple different scanner models. The onsite physicist provides technical education for imaging personnel, which is necessary for them to safely perform high quality imaging procedures. Finally, MRI physicists work closely with the manufacturer's application specialists to customize exam parameters for the needs of their specific practice.

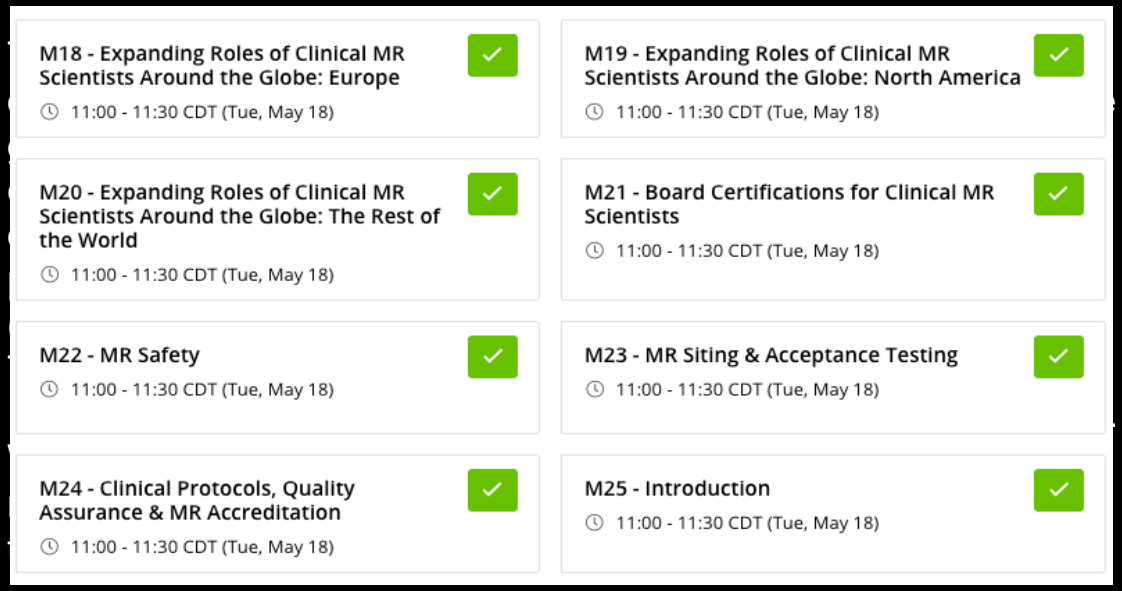
Safety & Risk Management

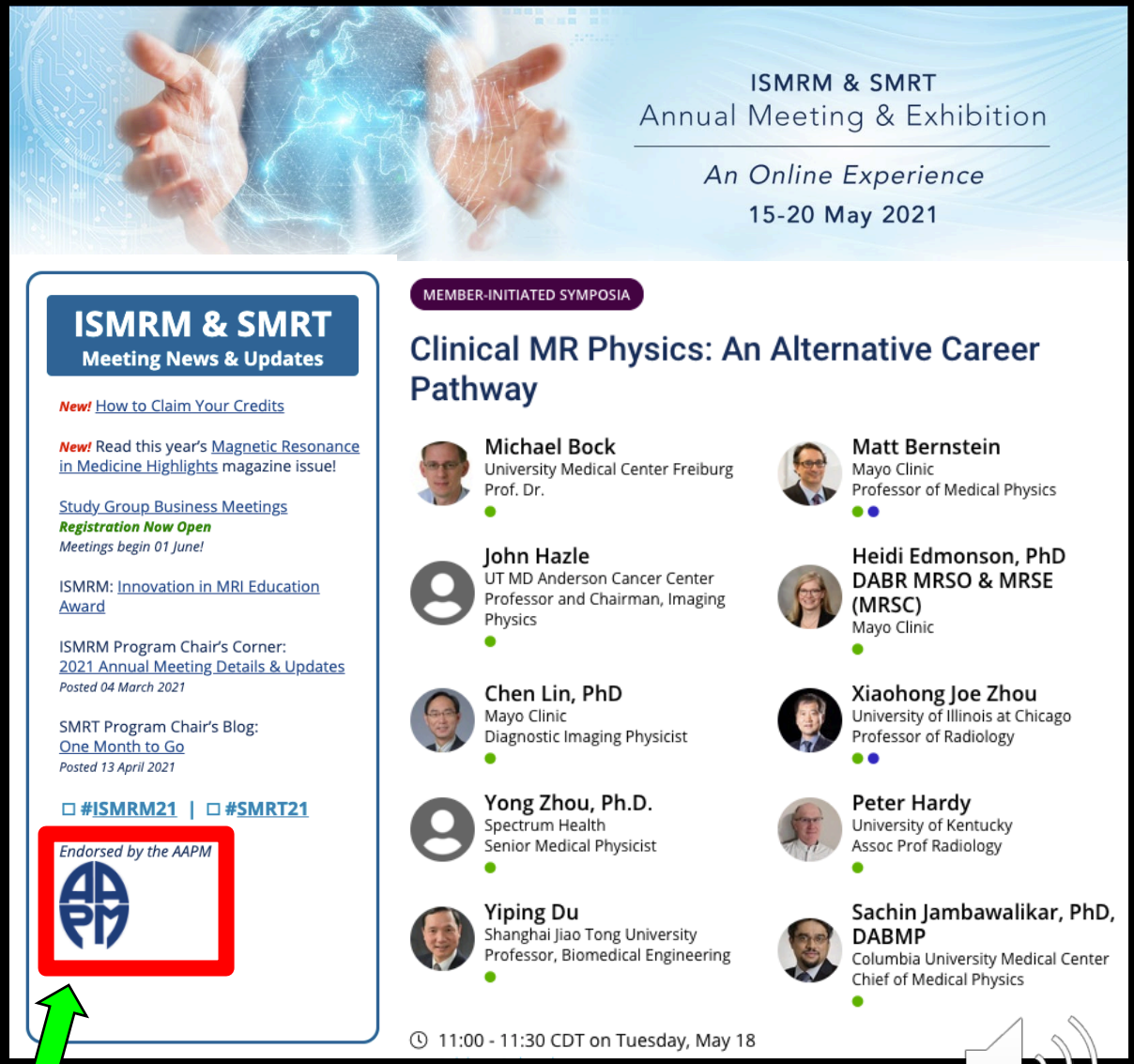
The onsite MRI physicist serves as an expert resource for MRI safety and may be asked to join or lead the MRI safety committee. They develop policies and procedures, address siting safety issues, review the MRI safety program, evaluate objects that may need to be used in the MRI environment, and provide annual safety training courses. A critical function is participating in the care of patients who have MR Conditional devices or implants. In these situations, the MRI physicist must perform a risk assessment, select safe technical parameters and equipment, modify the imaging protocol as needed, and oversee the imaging procedure. Such expertise is invaluable to these patients, who might otherwise be unable to undergo medically necessary MRI exams or procedures.

Fostering a community for MR physics

Overview: Clinical MR physics plays a key role in translating MR research to clinical practice. The demand for clinical MR scientists is increasing globally, yet the ISMRM has not held a focused session on the professional aspects of clinical MR physics.

The proposed symposium addresses this unmet need with two objectives. First, we will systematically discuss aspects of clinical MR physics to benefit the growing number of clinical MR scientists in the ISMRM community. Second, we will provide a practical guide to our trainee members on an alternative career pathway in clinical MR physics.





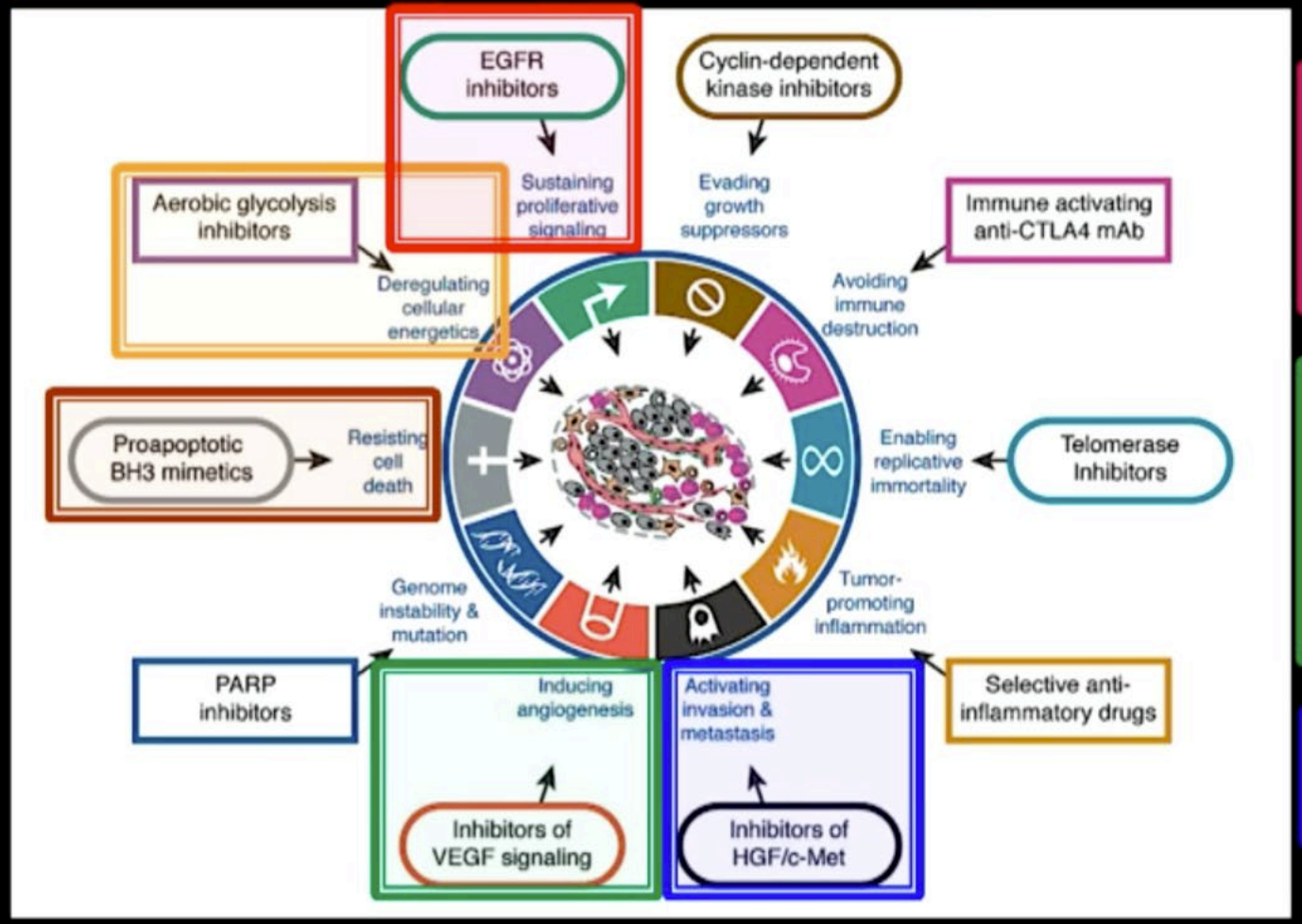
https://ismrm-smrt21.us3.pathable.com/meetings/virtual/fhB5RyJSKiXHSoy4q

Organizers: Xiaohong Joe Zhou, Matt Bernstein, H. Doug Morris

Imaging Applications in Precision Medicine

^{18}F/^{99m}Tc-Annexin V
Diffusion MRI

^{18}F-FLT PET
Diffusion MRI
^{1}H MR Spectroscopy



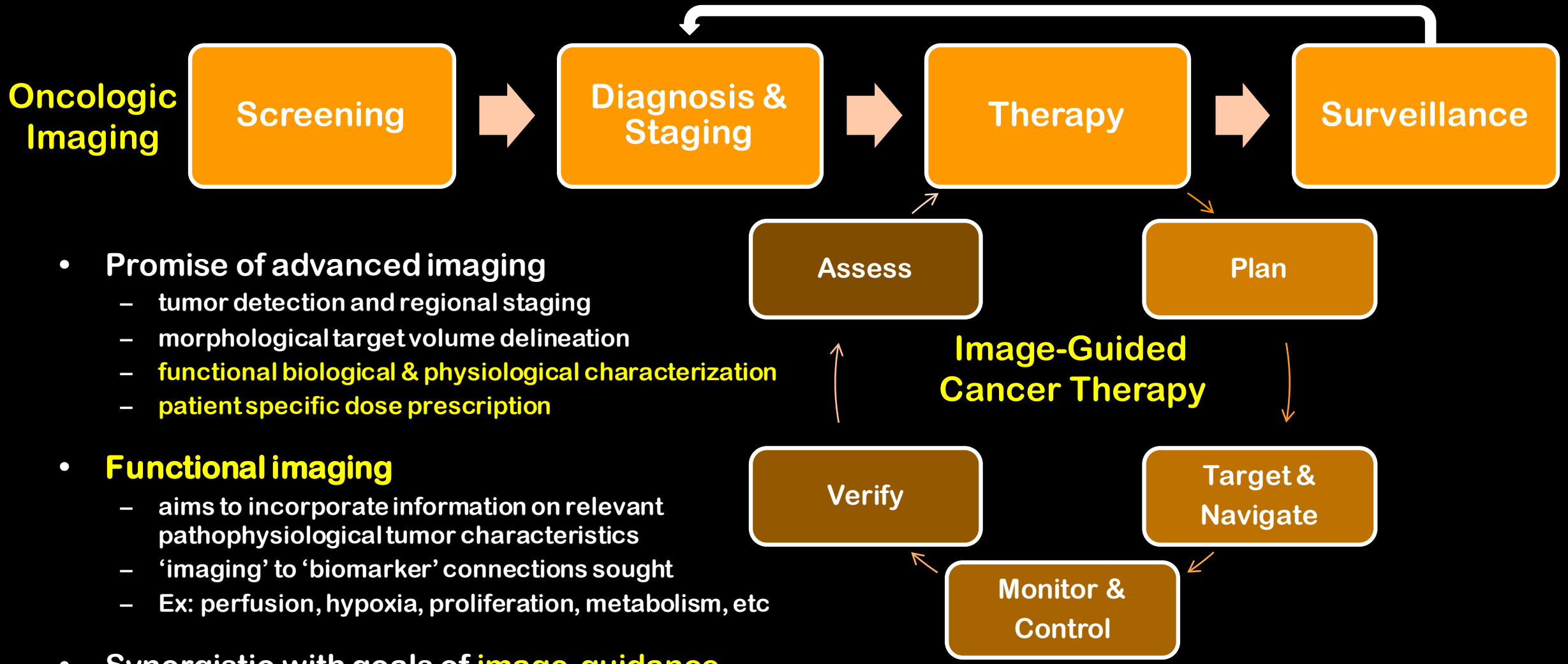
Hanahan & Weinberg, Hallmarks of Cancer: The Next Generation, *Cell* 144:646-674, 2011

^{18}F-FDG PET
^{18}F-MISO PET
^{1}H & ^{13}C MR Spectroscopy
BOLD MRI

DCE-MRI / DCE-CT
DSC-MRI / ASL MRI
CE-US
^{68}Ga-/^{64}Cu-DOTA-cRGD PET
^{89}Zr-bevacizumab

^{18}F-FDG PET
Diffusion MRI

Functional imaging in oncology



- Promise of advanced imaging
  - tumor detection and regional staging
  - morphological target volume delineation
  - functional biological & physiological characterization
  - patient specific dose prescription
- **Functional imaging**
  - aims to incorporate information on relevant pathophysiological tumor characteristics
  - 'imaging' to 'biomarker' connections sought
  - Ex: perfusion, hypoxia, proliferation, metabolism, etc
- Synergistic with goals of image-guidance
  - target tumor and spare normal tissue
  - increase safety + efficacy
  - 'close the loop'

Functional MR Imaging: Examples in Oncology

Techniques such as DWI & DCE facilitate physiological tumor property measurements*

Angiogenesis, perfusion & hypoxia

DCE	**Dynamic Contrast Enhanced**	**Microvascular permeability; blood perfusion Volume fractions (blood plasma & EES)**
DSC	Dynamic Susceptibility Contrast	Blood volume/flow, mean transit time
ASL	Arterial Spin Labeling	Blood flow
BOLD	Blood Oxygen Level Dependent	Blood pool oxygenation
TOLD	Tissue Oxygen Level Dependent	Tissue pool oxygenation

Cellular density, proliferation & tissue microstructure

DWI	**Diffusion Weighted Imaging**	**ADC (apparent diffusion coefficient)**
IVIM	Intravoxel Incoherent Motion	ADC; pseudo-diffusion; fractional flow volume
DKI	Diffusion Kurtosis Imaging	Mean kurtosis, radial/parallel kurtosis
DTI	Diffusion Tensor Imaging	Diffusion anisotropy, tractography
MRE	MR Elastography	Tissue elasticity & viscosity

Metabolism

MRS	MR Spectroscopy	Accumulated metabolites
CEST	Chemical Exchange Saturation Transfer	Endogenous/exogenous metabolites; pH
hpMRI	Hyperpolarized MRI	Exogenous agent metabolic activity (i.e., LDH)

*Shukla-Dave A, Jackson EF, et al. J Magn Reson Imaging. 2019 Jun;49(7):e101-e121.

EES = extravascular extracellular space

Science to Practice: Redux

- Current innovations in science will drive new practice
  - Quantitative Imaging Biomarkers
  - Artificial Intelligence
- Physicists now in strong position to participate in the process
  - development, implementation, measurement & control, review & improve
- To adapt, need to maintain a firm commitment to academic and professional education
- Fostering future generations of capable servant leaders in Medical Physics, ready to work collaboratively to continuously improve and move the science & profession forward may be part of the key to success

THE UNIVERSITY OF TEXAS

MD Anderson Cancer Center

Thank you for your time!

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