“REINVENTING RADIOLOGY IN THE TWENTY-FIRST CENTURY”

Michigan Radiological Society: Centennial Gala and Education Event

October 23, 2021

James H Thrall MD

Chairman Emeritus

Department of Radiology

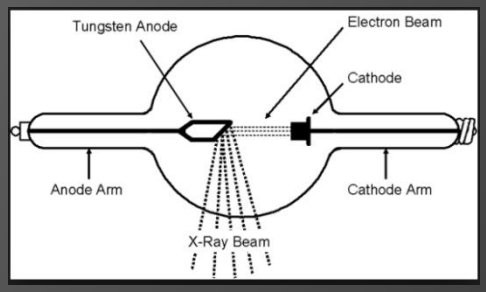
Massachusetts General Hospital

Distinguished Juan M Taveras Professor of Radiology

Harvard Medical School

A Quick Trip Down Memory Lane

Prelude to the 21st Century



1895–1970: THE ERA OF X-RADIOLOGY

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots, \qquad -\infty < x < \infty$$

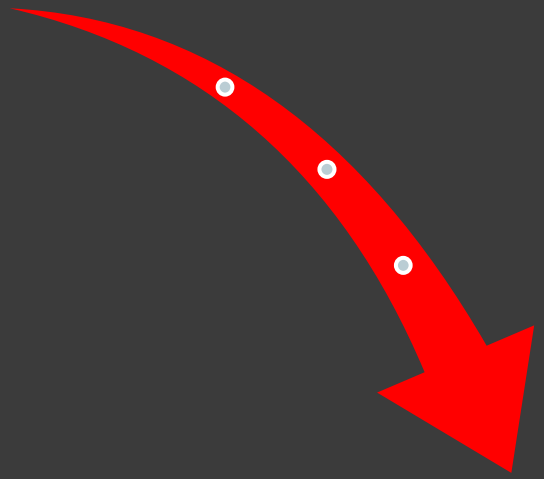
- Radiography
- From plates to film
- Frontal tomography—limited view angle
- Contrast media
- Fluoroscopy
- Angiography
- Automated film processing
  - 1940s– 40 minutes
  - 1950s– 9 minutes
  - 1960s– 90 seconds

Analog imaging

Images regarded as “Pictures”

1965—1985: Era of New Modality Development And Implementation

- Ultrasound
- NM SPECT
- NM PET
- CT
- MRI
- Digital angio

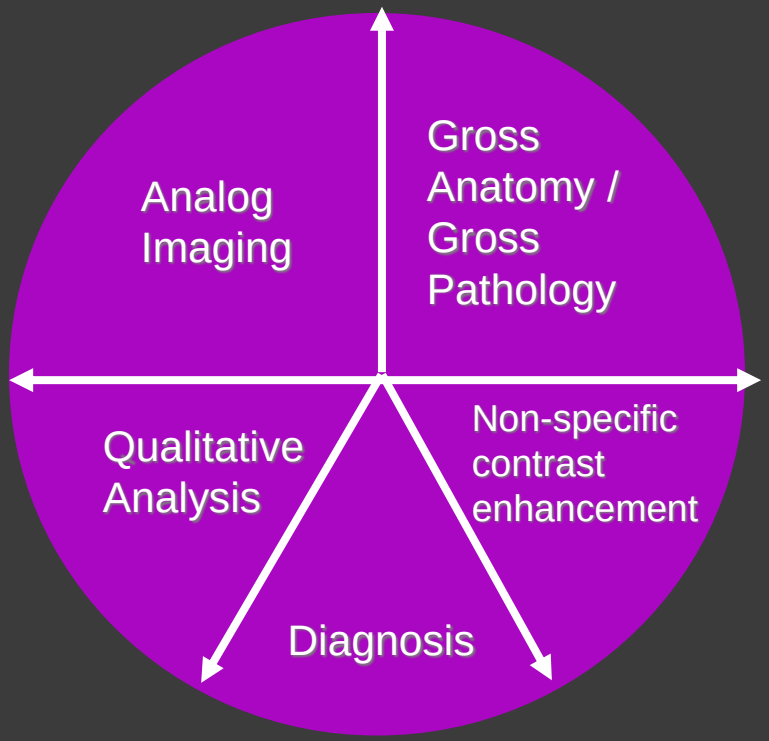


2020s

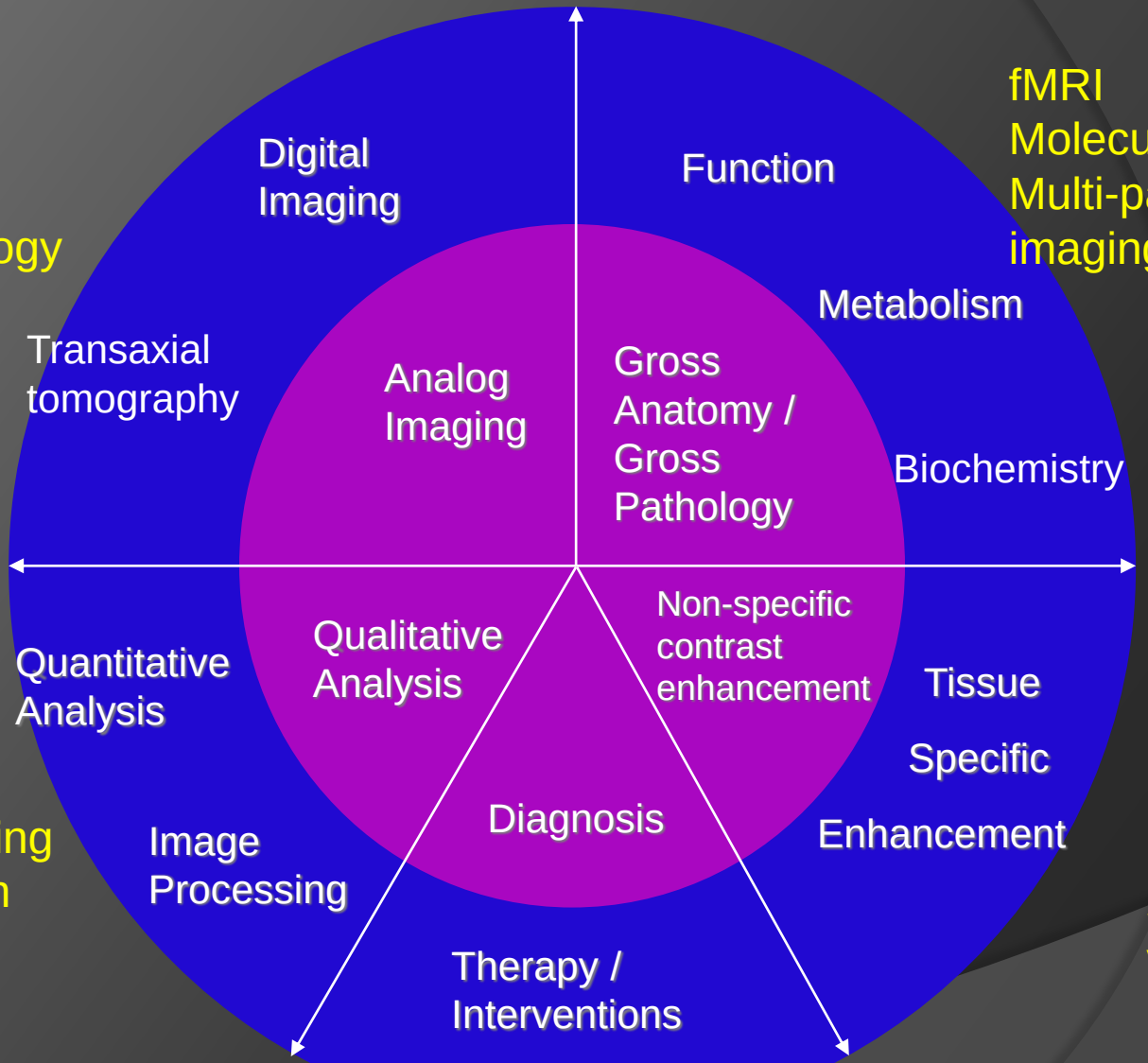
80--85% of imaging RVUs

1980–2000 ERA OF FUNDAMENTAL TRANSFORMATIONS

HISTORIC THEMES IN MEDICAL IMAGING



Key Transformations in Radiology



PACS
Voice rec
RIS,
Teleradiology

fMRI
Molecular imaging
Multi-parametric imaging

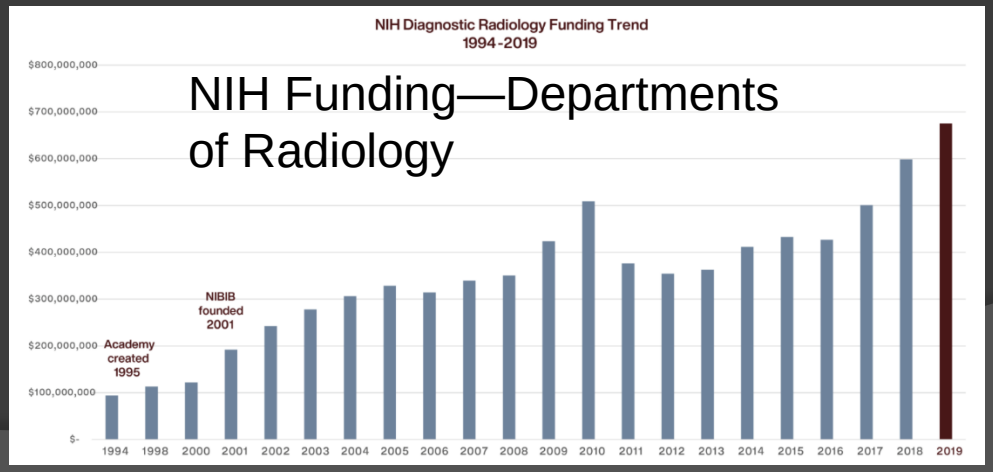
Hybrid imaging
Image fusion
3D display

Organ system visualization

Interventional radiology

- Digital images become regarded as “Data”—pixels are numbers
- Imaging “biomarkers” conceptualized–parameters that radiology can detect and measure
- Molecular imaging
- Functional Imaging

Basis for the rise of radiology in biomedical research

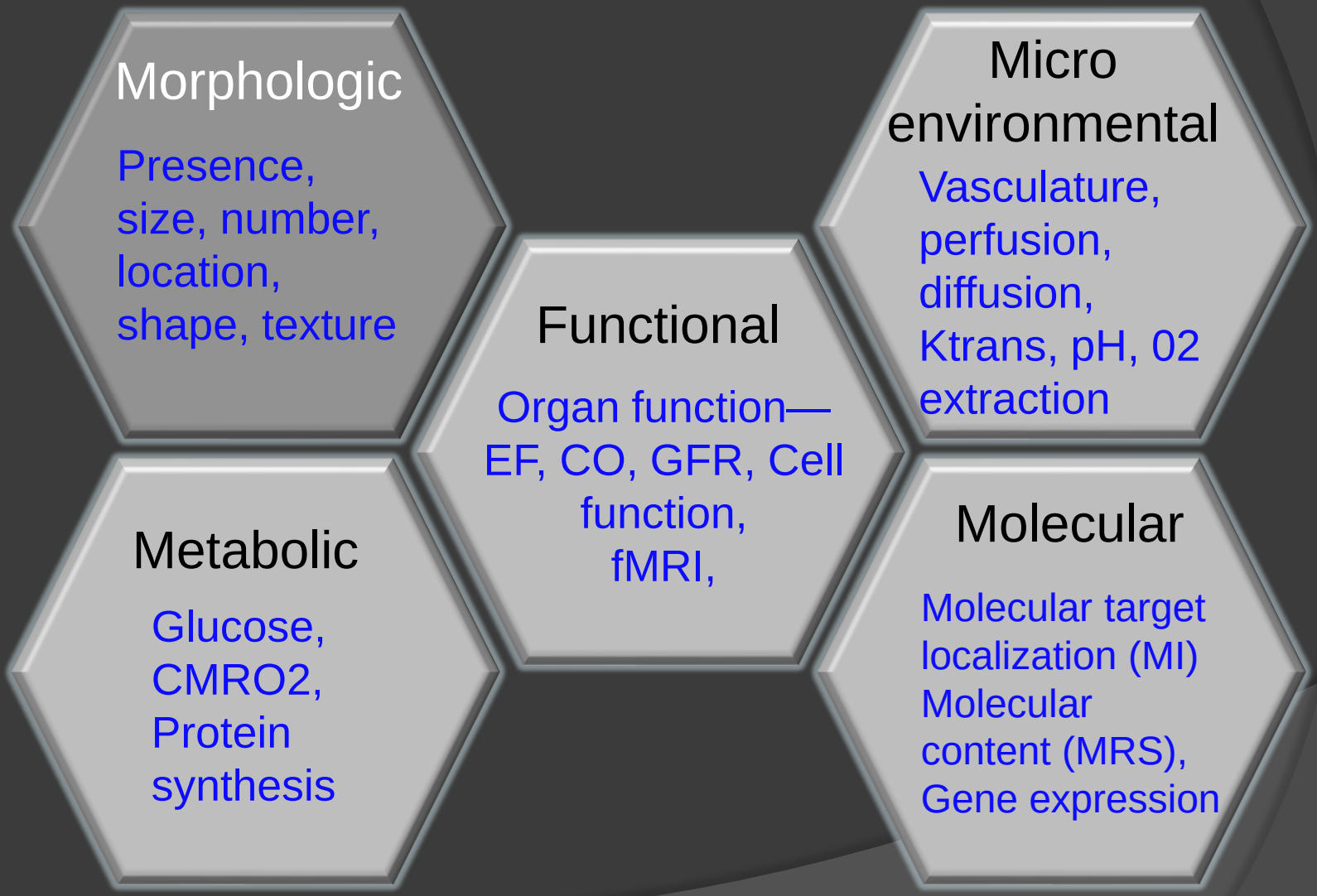


From Academy for Radiology Research

Imaging Biomarkers-- 1965

Imaging biomarker: Any image finding that establishes the presence, location or severity of disease or otherwise characterizes normal and diseased tissues

Imaging Biomarkers-- 2005



What's left?

21ST CENTURY: REINVENTION CONTINUES

21st Century

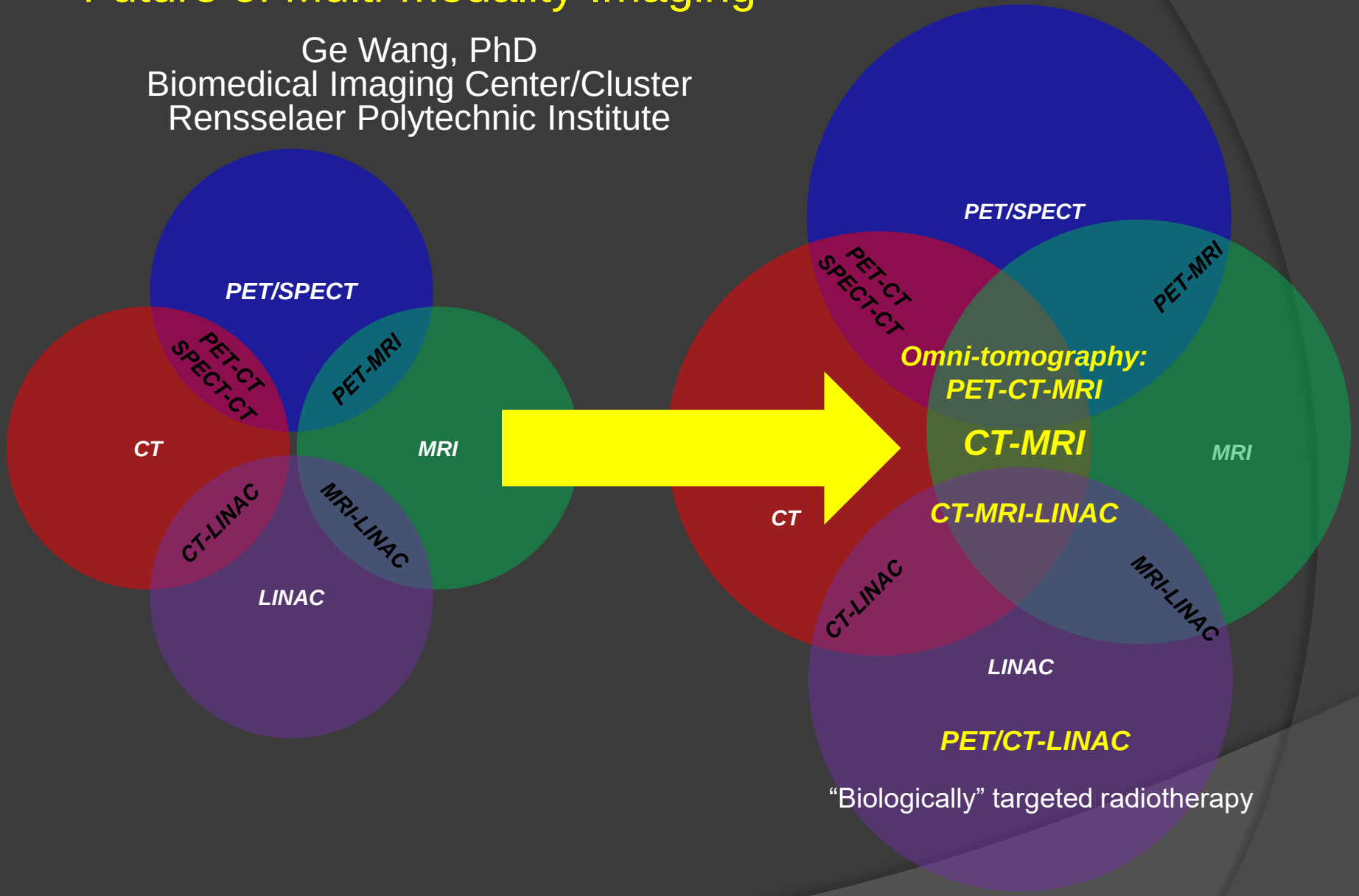
New and Improved Imaging Methods

All Existing Methods Continue To Be Improved

- Faster– 5 min head MRI
- Lower radiation dose– 1.0 mSv, 2.0 second heart CCTA
- Image fusion
- Multi-parametric imaging– prostate MRI
- High Tech bedside imaging—CT, MRI
- “Omni tomography” -- Hybrid imaging
- …

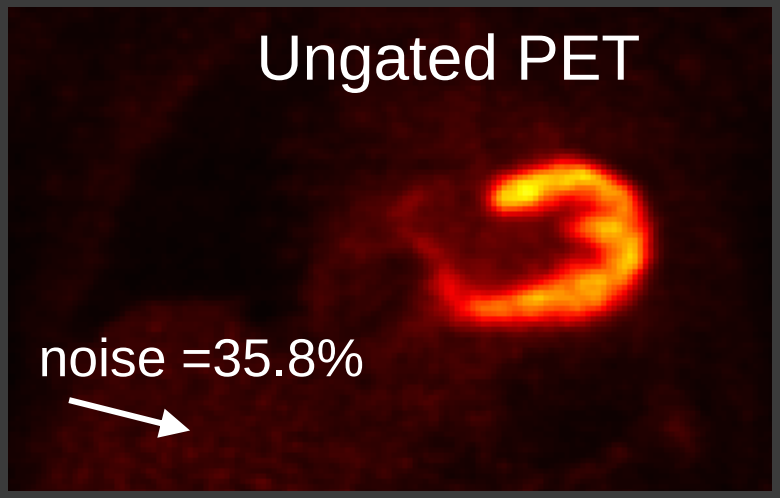
Future of Multi-modality Imaging

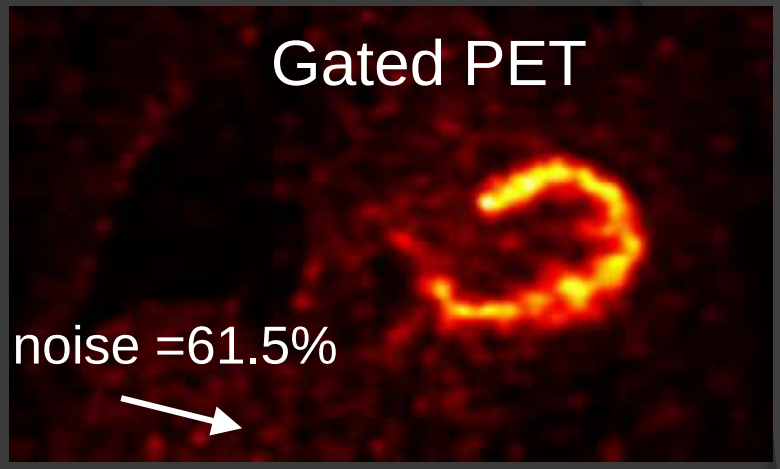
Ge Wang, PhD
Biomedical Imaging Center/Cluster
Rensselaer Polytechnic Institute



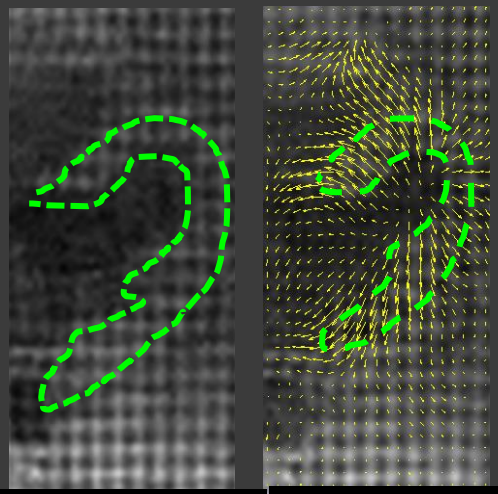
"Omni-tomography"

Impact of Respiratory and Cardiac Motion in PET-MR



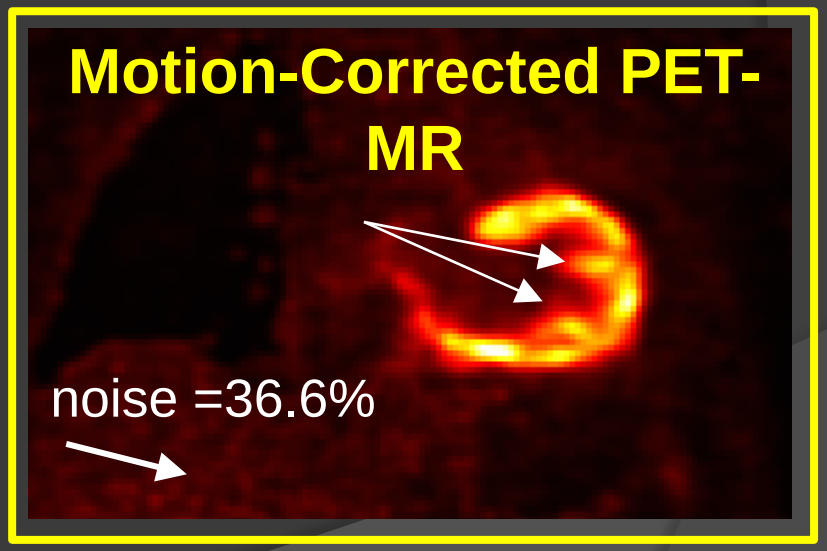


Measurement of cardiac motion by MR tagging



tMR-End-diastole

tMR-End-systole



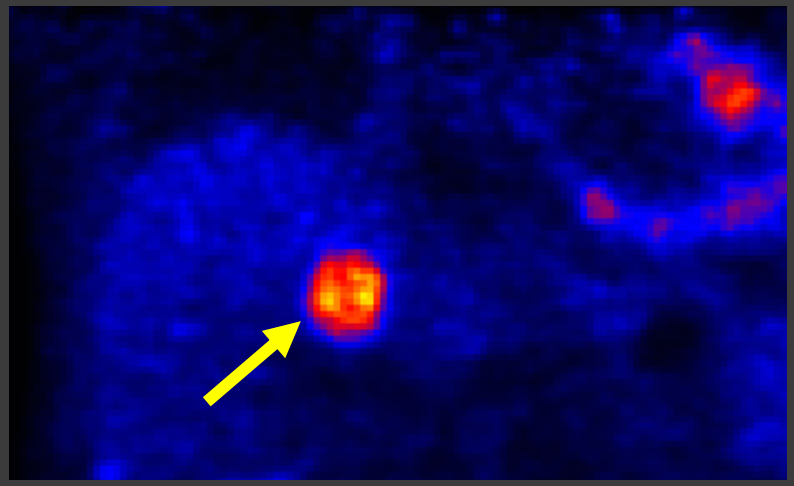
Courtesy Dr G. El Fakhri

Gordon Center Medical Imaging

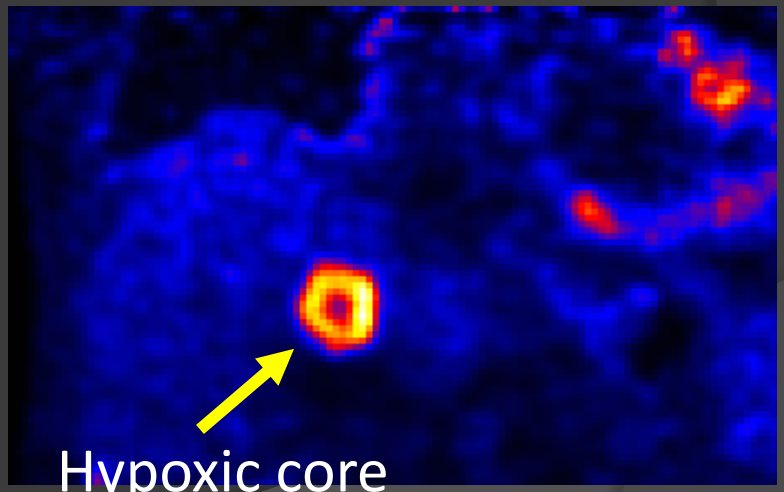
Simultaneous PET/MR in hepatic cancer

MR (T1w)

PET-CT



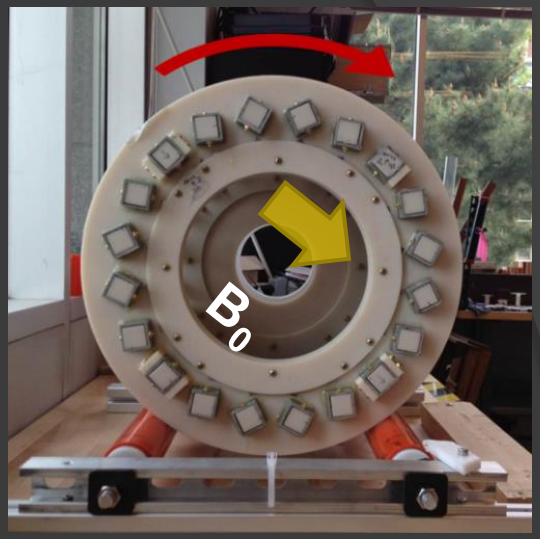
PET-MR
(Motion + PSF correction)



Courtesy Dr G. El Fakhri

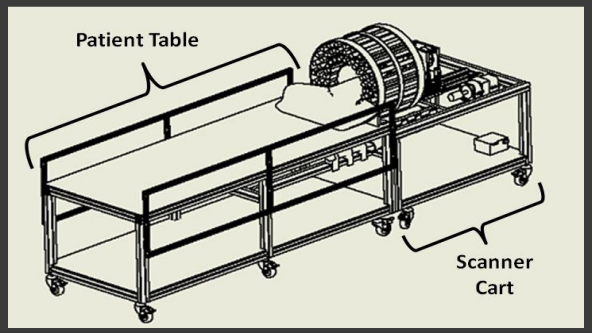
Portable MRI

- Magnet: rotating permanent magnet (Halbach cylinder)
- Low-power: no gradient coils or amplifiers
- Lightweight: < 100 kg
- Safe: low-field magnet (77mT)
- No cooling requirements
- Low-cost: ~$25,000



46 cm

Prototype rotating magnet



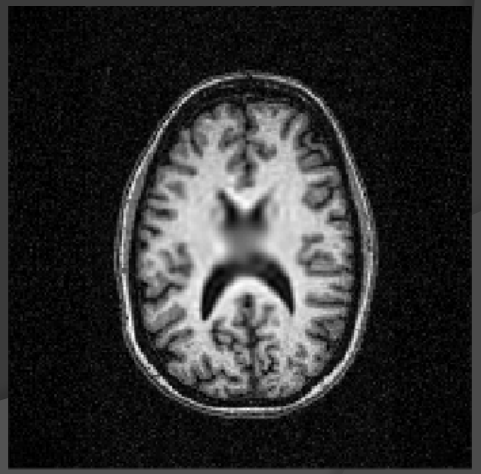
Proposed portable MRI scanner

Clarissa Zimmerman Cooley, Jason P. Stockmann, Matthew S Rosen, Lawrence L. Wald, Martinos Center—MGH, MIT, Harvard

Experimental image

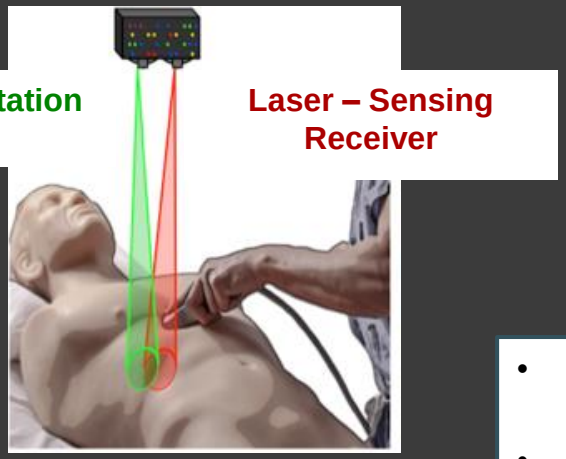
16 cm

Simulation of brain image with prototype magnet

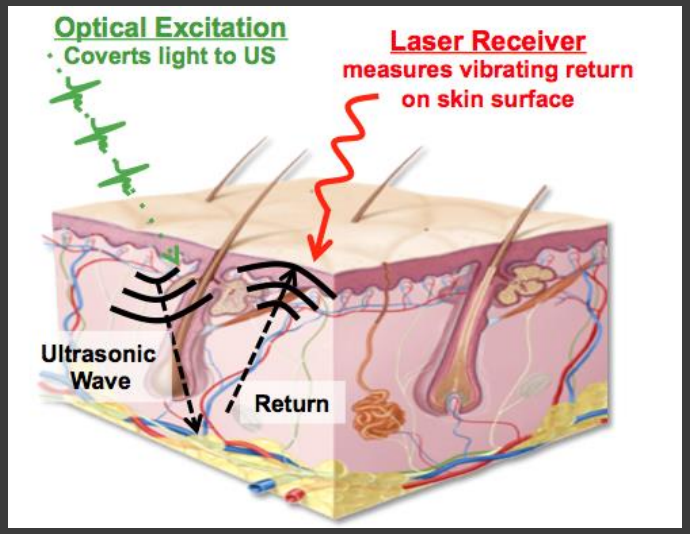


SCALED SIMULATION

Non-Contact Laser-Ultrasound (NCLUS) for Medical Imaging



Standoff Laser Ultrasound System Concept



NCLUS Advantages

- **Operator independent-- mitigates operator variability - enables higher confidence in change detection**
- **Requires no gels, skin prep or probe sterilization**
- **Applicable to healthy or burned skin, traumatized body areas, open surgical regions, others**
- **Low cost, easily portable**
- **Imaging capability competitive with MRI and CT**

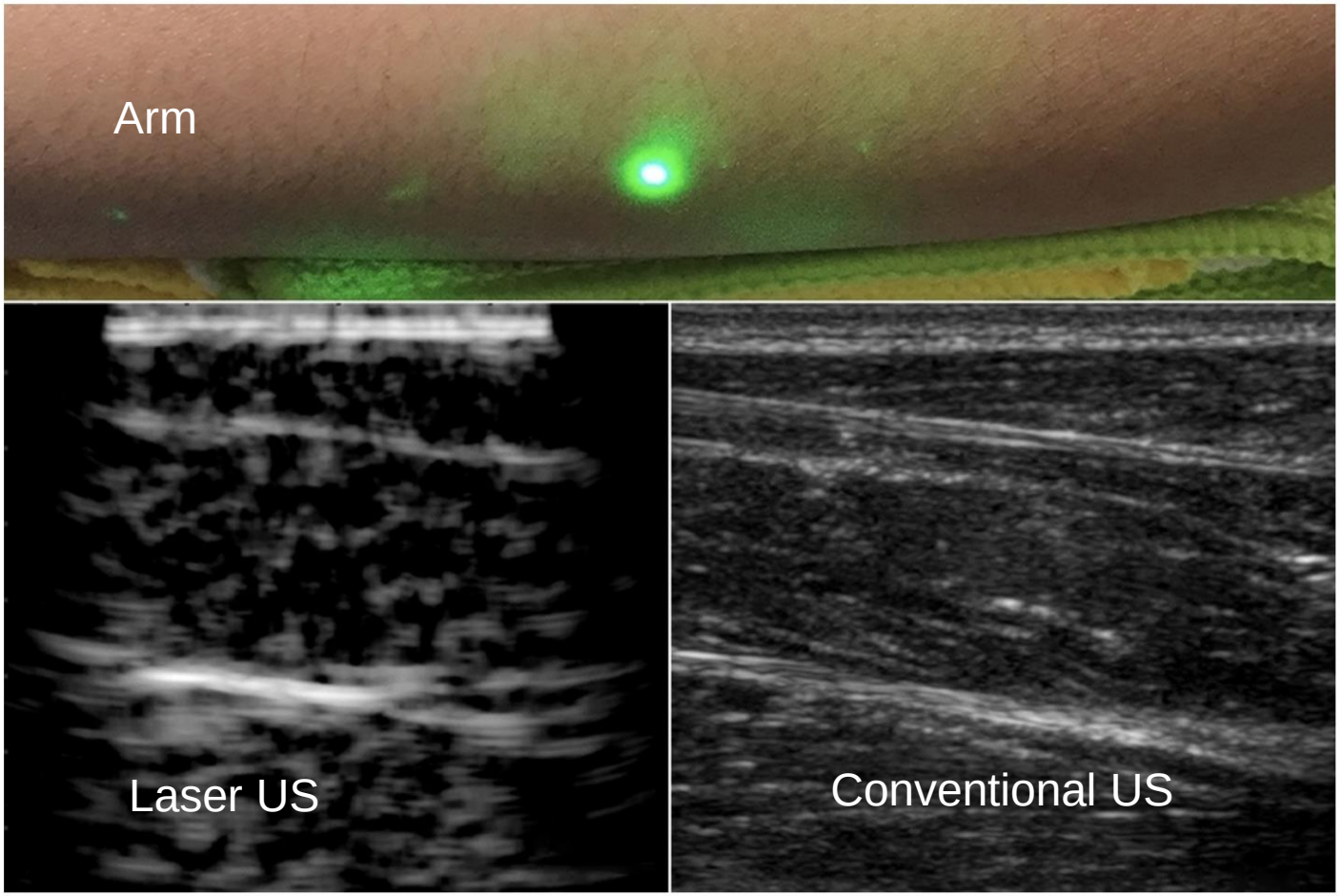
Lincoln Lab, MGH, and MIT developing non-contact optical ultrasound imaging system for portable field forward and in-hospital environments

B Anthony, MIT; A Samir, MGH; R Haupt, Lincoln Labs

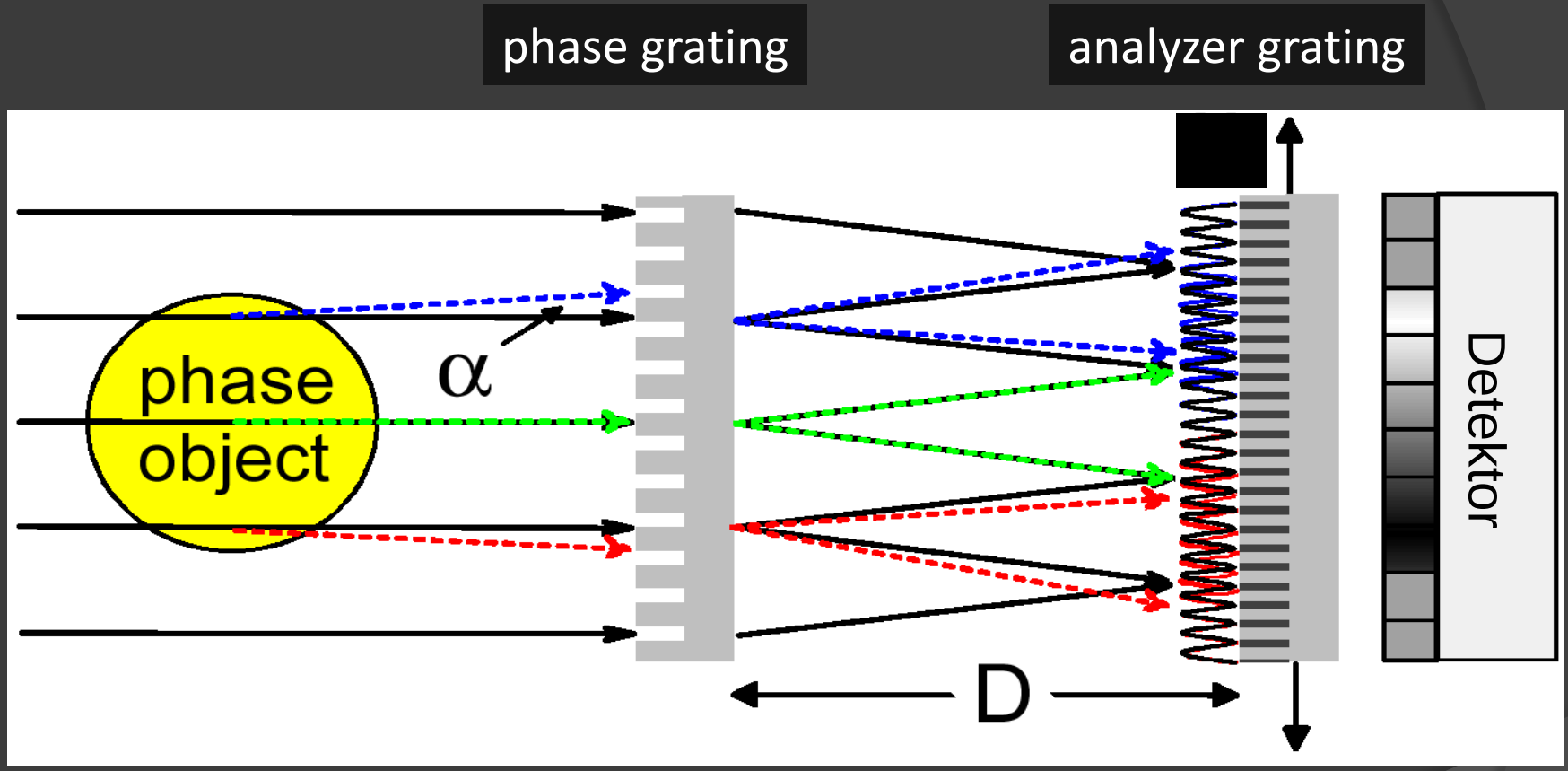
Researchers produce first laser ultrasound images of humans

Technique may help remotely image and assess health of infants, burn victims, and accident survivors in hard-to-reach places.

Jennifer Chu | MIT News Office
December 19, 2019



Phase-Contrast Imaging: X-Ray Optical Gratings



Momose et al | Optics Express | 2003
Weitkamp et al | Optics Express| 2005
Pfeiffer et al | Physical Review Letters | 2005

Courtesy of E Rummeny, F Pfeiffer, Technical University of Munich

X ray Phase Contrast Imaging

Material	**μ (cm^{-1}) at 60keV**	**Φ (cm^{-1}) at 60keV**	**Ratio**
H2O	0.2061	195.5	949
dH2O	0.2267	215.1	949
Ethenol	0.1582	156.6	990
Glycerin	0.2477	140.7	568
Fat	0.1793	180.7	1008
Liver	0.2174	205.2	944
Sources:		~1000:1 contrast advantage for soft tissues	
ICRP (1975)			
Woodard and White (1986)			

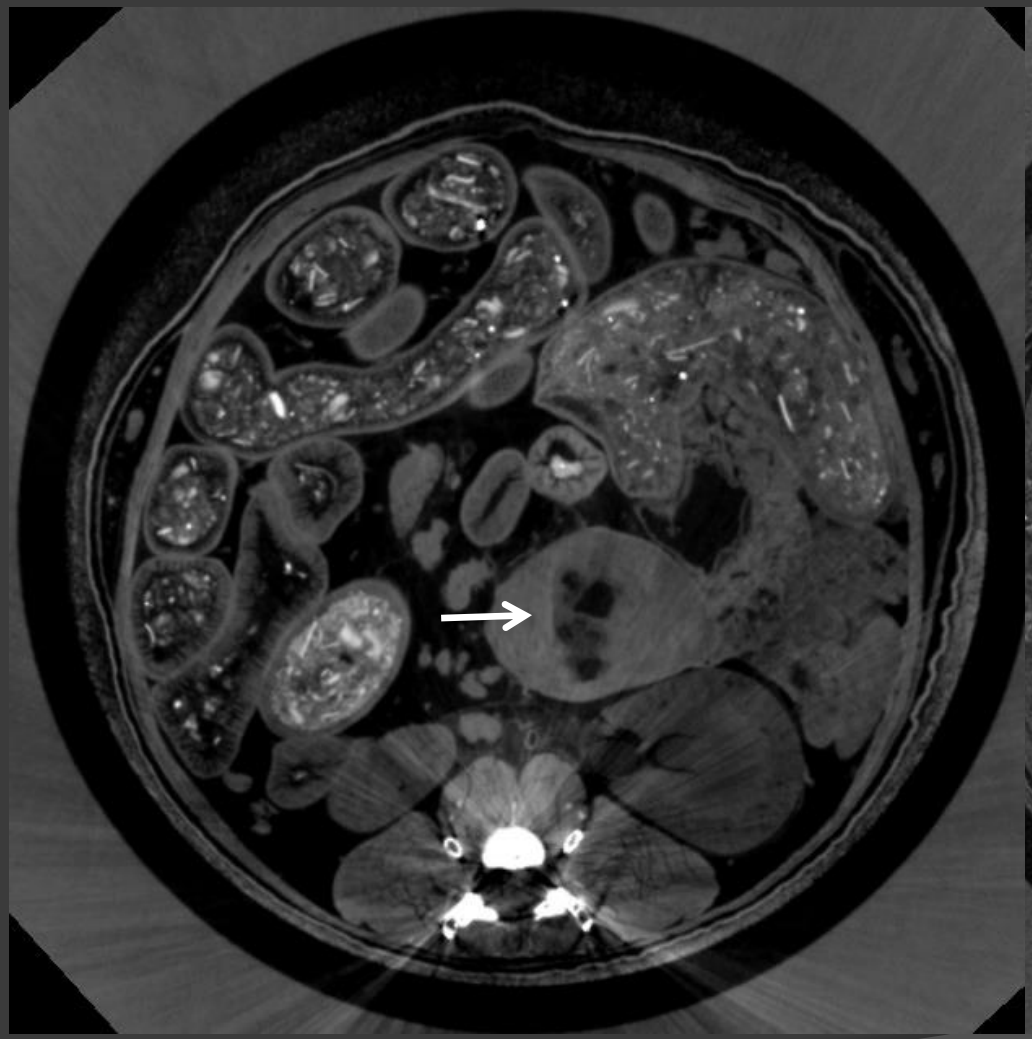
First Phase Contrast Image with MGH/MIT Portable Phase Imaging Device

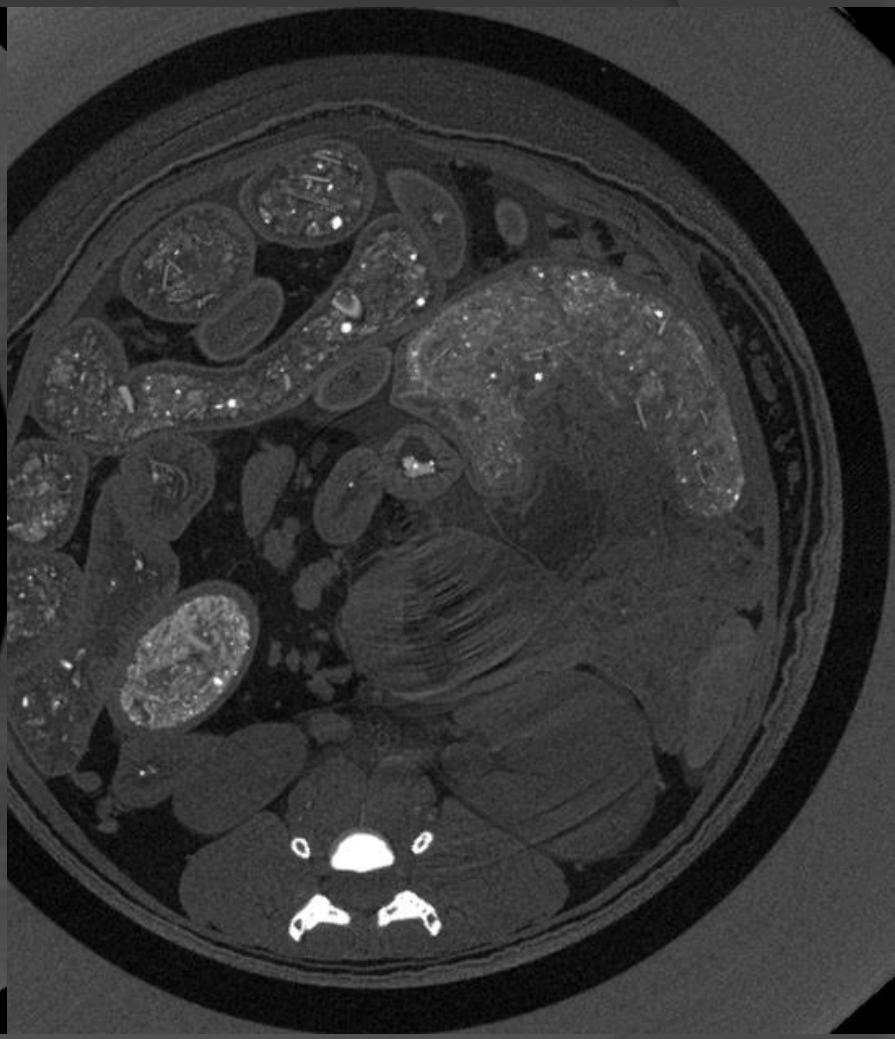
Images courtesy of R Gupta, MGH

Rat: Pancreas-Ca., Central necrosis

Phase Contrast CT

Absorption CT





Courtesy of E Rummeny, F Pfeiffer, Technical University of Munich

21st Century

New Information Management Applications

Boland et al., *JACR* 2011. http://www.jacr.org/article/S1546-1440(11)00442-X/fulltext

Reduce confusing variation between reports

Develop more evidence-based best practice standards

Improve adherence to them

Integrate Decision Support program seamlessly into radiologists' work process

Management of Incidental Adrenal Masses: A White Paper of the ACR Incidental Findings Committee

EC: Editor's Choice

SA-CME

William W. Mayo-Smith, MD[a], Julie H. Song, MD[b], Giles L. Boland, MD[a], Isaac R. Francis, MD[c], Gary M. Israel, MD[d], Peter J. Mazzaglia, MD[e], Lincoln L. Berland, MD[f], Pari V. Pandharipande, MD, MPH[g]

Abstract

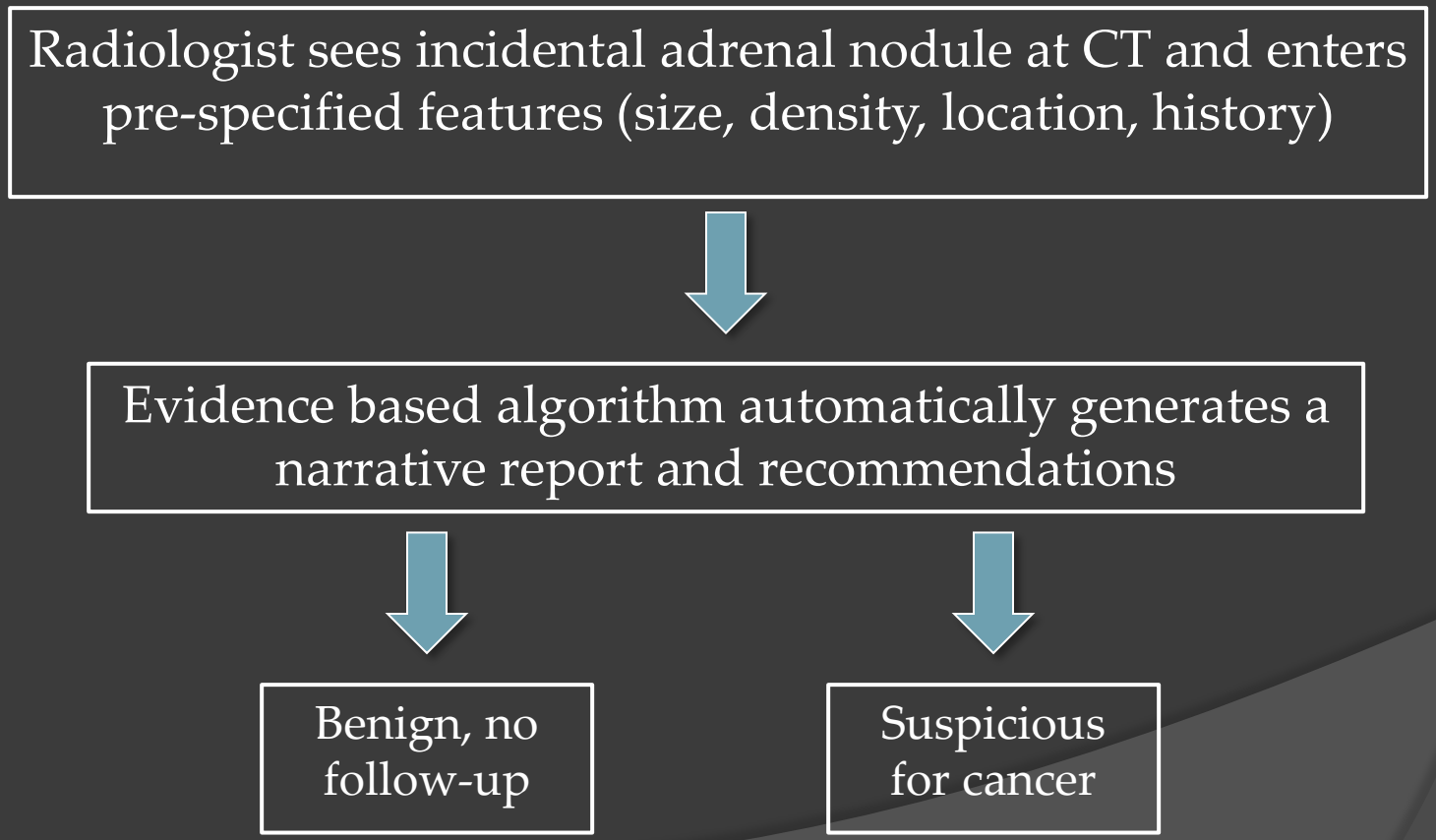
The ACR Incidental Findings Committee presents recommendations for managing adrenal masses that are incidentally detected on CT or MRI. These recommendations represent an update to the adrenal component of the *JACR* 2010 white paper on managing incidental findings in the adrenal glands, kidneys, liver, and pancreas. The Adrenal Subcommittee, constituted by abdominal radiologists and an endocrine surgeon, developed this algorithm. The algorithm draws from published evidence coupled with expert subspecialist opinion and was finalized by a process of iterative consensus. Algorithm branches categorize incidental adrenal masses on the basis of patient characteristics and imaging features. For each specified combination, the algorithm concludes with characterization of benignity or indolence (sufficient to discontinue follow-up) and/or a subsequent management recommendation. The algorithm addresses many, but not all, possible pathologies and clinical scenarios. Our goal is to improve the quality of patient care by providing guidance on how to manage incidentally detected adrenal masses.

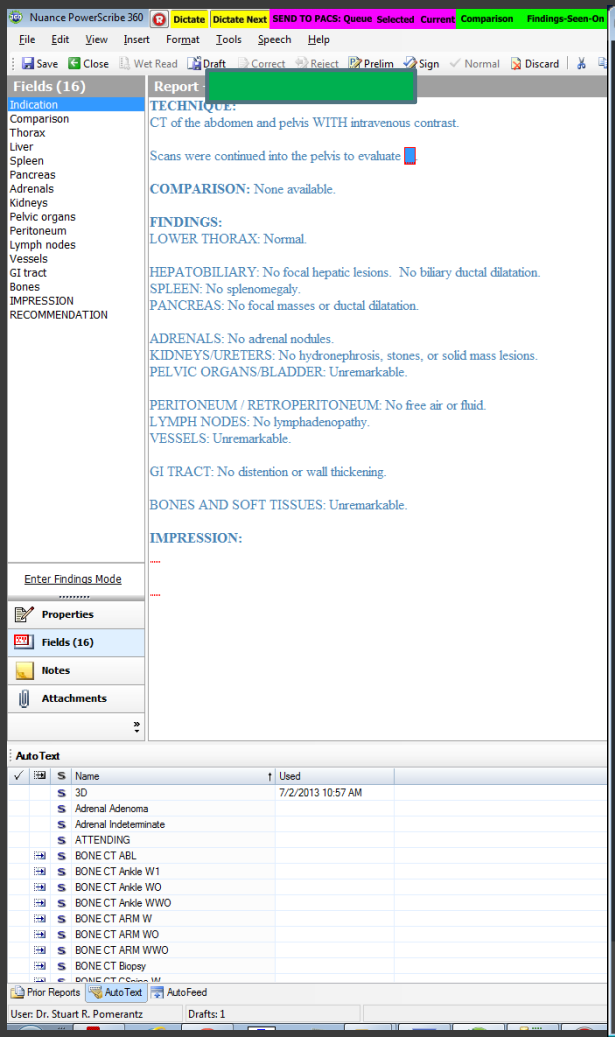
Key Words: Adrenal nodule, incidental findings, incidentaloma

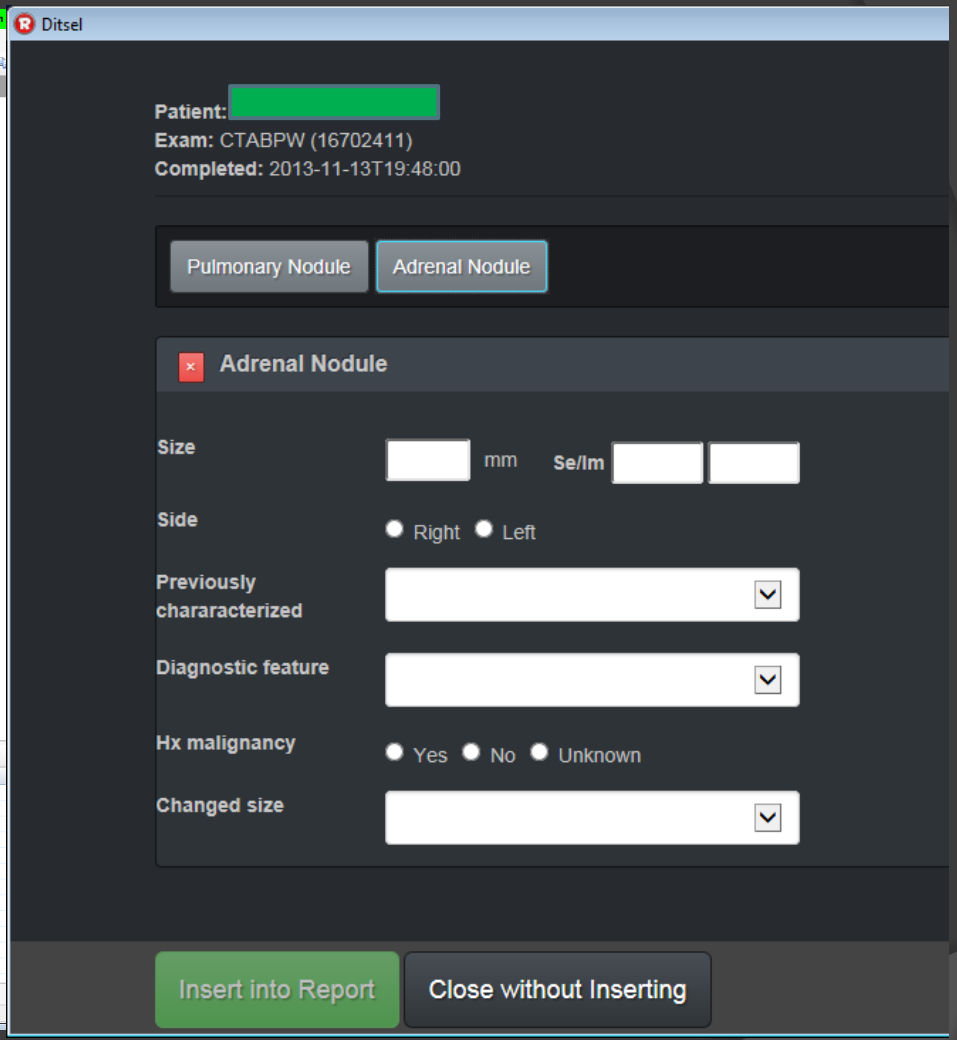
J Am Coll Radiol 2017;14:1038-1044.

How Decision Support for Radiologist Recommendations Works

Adrenal Nodule Algorithm

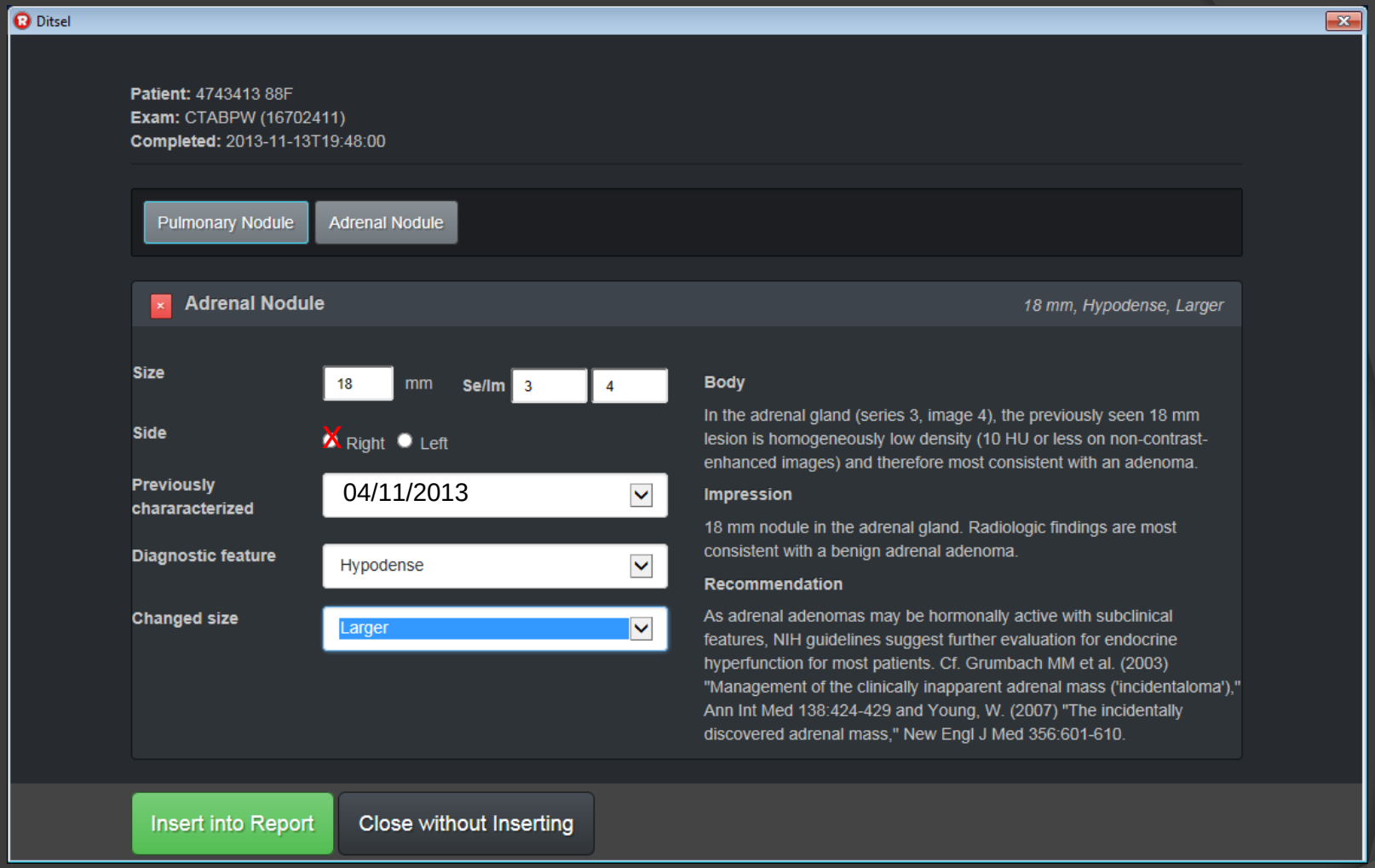






Structured report

Adrenal nodule specific template



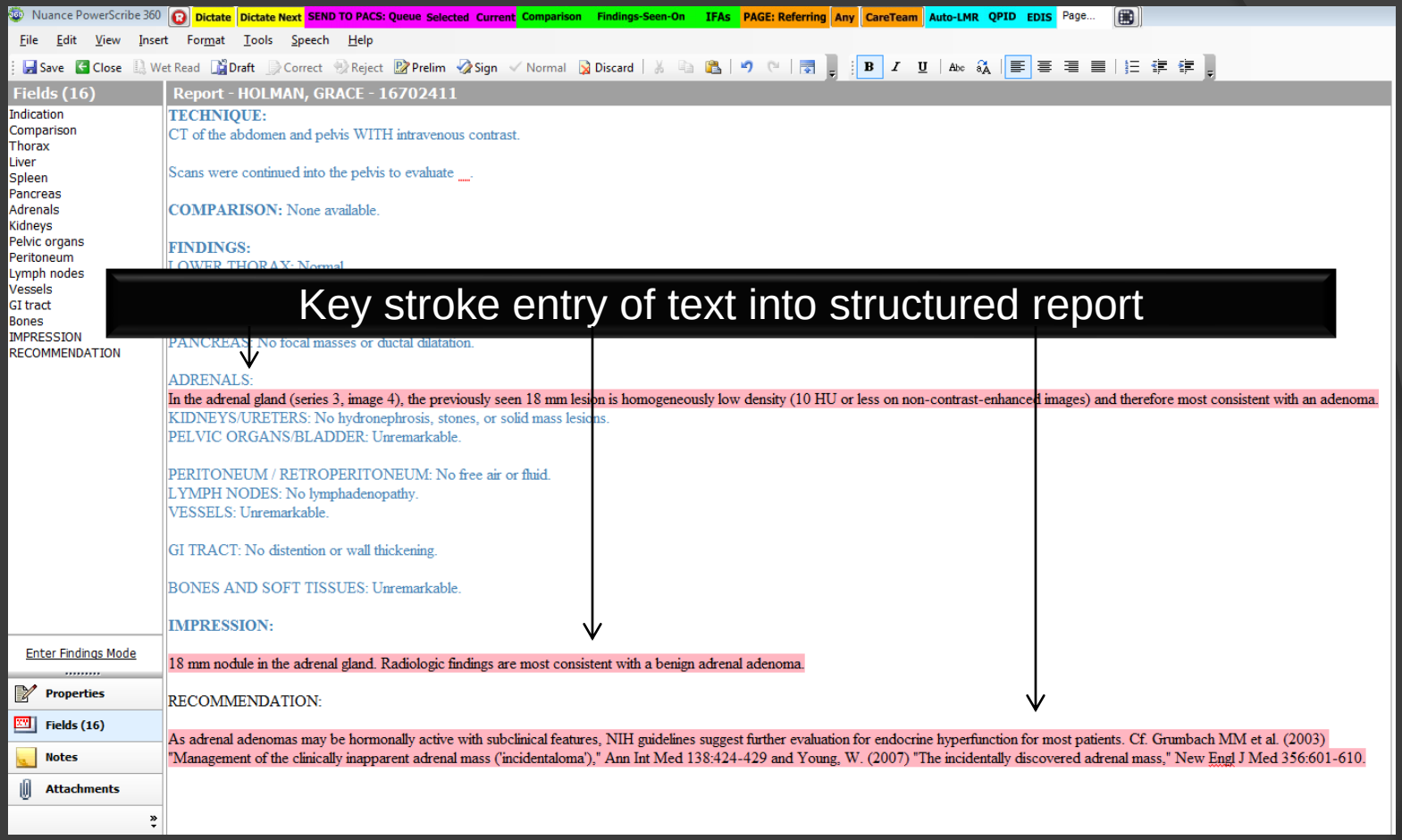
Characterizable Lesion

- Findings
- Impression
- Evidence-Based Clinical Recommendation

Body
In the adrenal gland (series 3, image 4) the previously seen right 18 mm lesion is homogeneously low density (10 HU or less on non-contrast enhanced images) and therefore most consistent with an adenoma.

Impression
18 mm nodule in the adrenal gland. Radiologic findings are most consistent with adrenal adenoma.

Recommendation
As adrenal adenomas may be hormonally active with subclinical features, NIH guidelines suggest further evaluation for endocrine hyperfunction for most patients. Cf. Gumbach MM et al. (2003) “Management of the clinically inapparent adrenal mass (“incidentaloma”). Ann Int Med 138: 424-429 and Young W (2007) “The incidentally discovered adrenal mass.” New Engl J Med 356: 601-610



Simultaneous Multi-Field Inserts

- Findings Field (nodule-specific subfield)
- Impression
- Recommendation

21st Century

Integrating the IT Forest

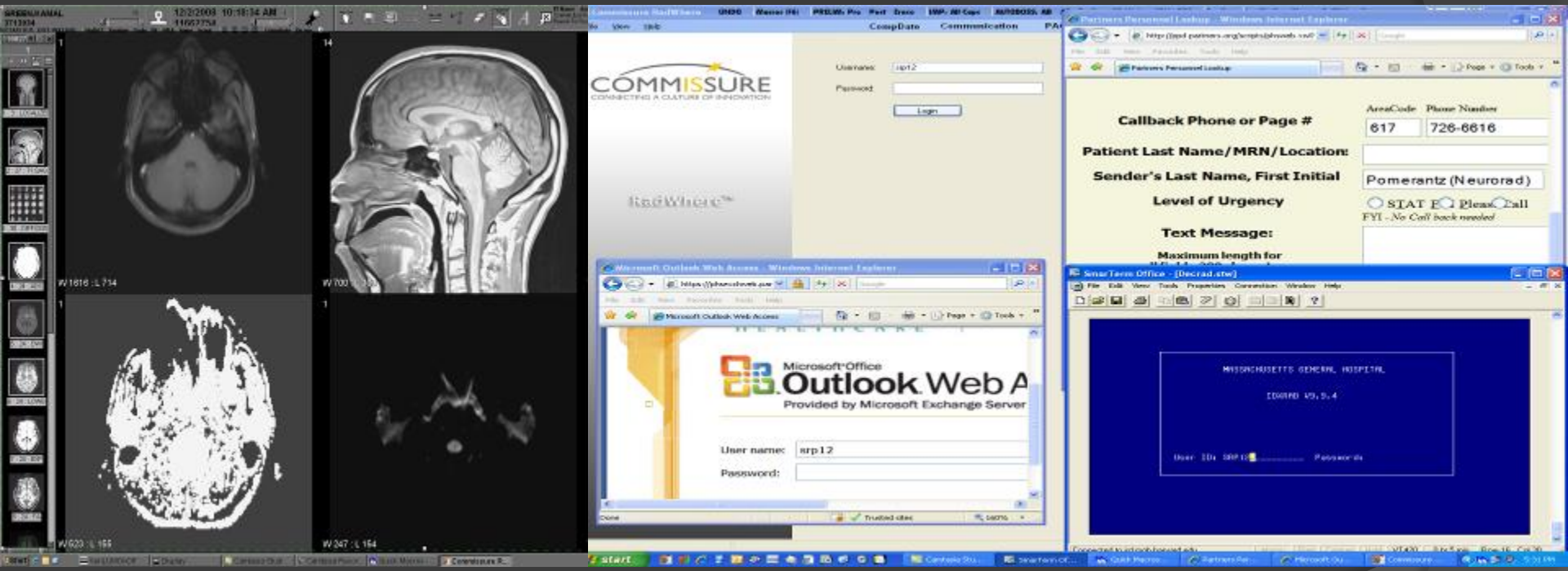
The Radiologist's Ergonomic Nightmare

Interpretation often navigated through 2 keyboards, 2 mice, 3-4 monitors, and a hand-held microphone

S Pomerantz, MGH

The Technology Integration Challenge:

Efficiency is degraded by the isolated manner in which the numerous imaging and informatics applications currently operate



Radiologists and other clinicians experience **physical and mental fatigue, waste time and make errors** -- continual re-entry of the same patient information into separate PACS, RIS, EMR, Dictation/Voice Recognition, Email, Paging, Teaching File, and Research Database applications

S Pomerantz, MGH

RADFUSION: Context-sensitive IT and Work Process Integration

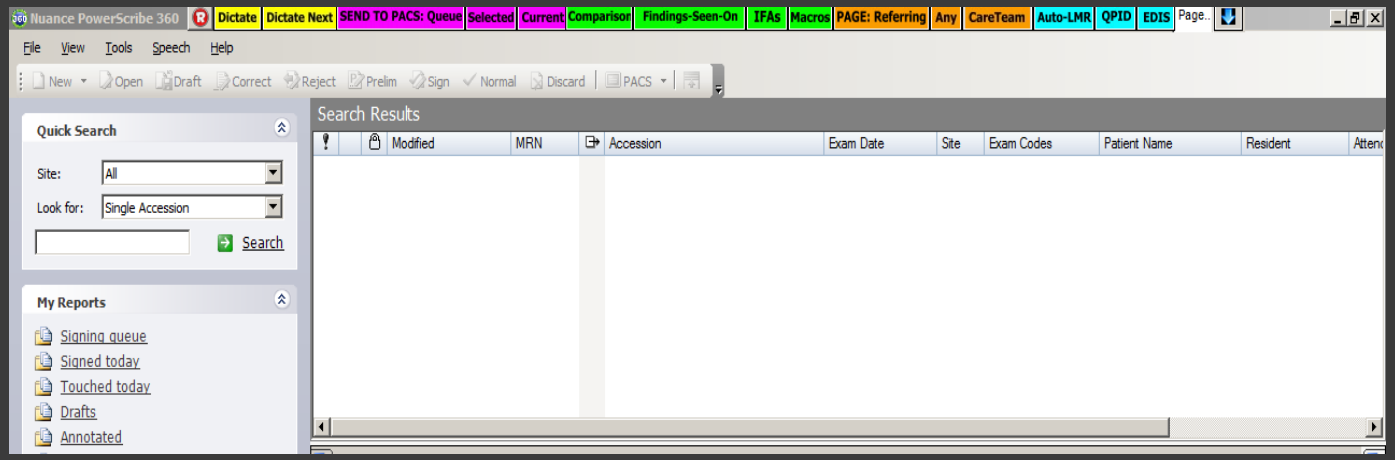
- **INTEGRATION**: meshwork of customized flexible conduits for automated information exchange between all informatics applications

- **CONTEXT-SENSITIVE**:
  - Radiologist- name, section, role (staff, trainee), phone number
  - Location – reading room, station, phone number
  - Patient – name, MRN, location, care team, allergies, meds, other EHR data
  - Study – exam type, date, modality, side, comparison studies
  - Referring physician– phone number, pager number, location

- **SEAMLESS**
  - Mediated either by a common interface (RadFusion Toolbar) OR
  - Appearing organic to the native applications

- **Author: Stewart Pomerantz, MGH Radiology**

RadFusion Toolbar Functions



- RadFusion Integration into Radiology Workflow
- RadFusion Toolbar “hung” on Nuance PowerScribe 360 Dictation application

Dictate

Worklist Transfer

Report Inserts

AutoPaging

Patient Refs

- Loads report to dictate for current case in PACS

- Transfers work list in Nuance to PACS

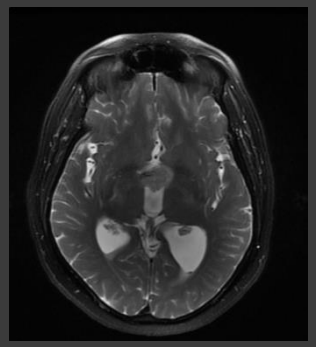
- Insert contextual text (e.g. Comparison study Date) into report

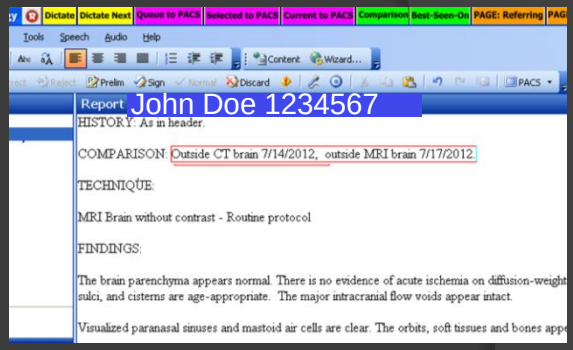
- Pages referring clinician with Critical Findings Alert

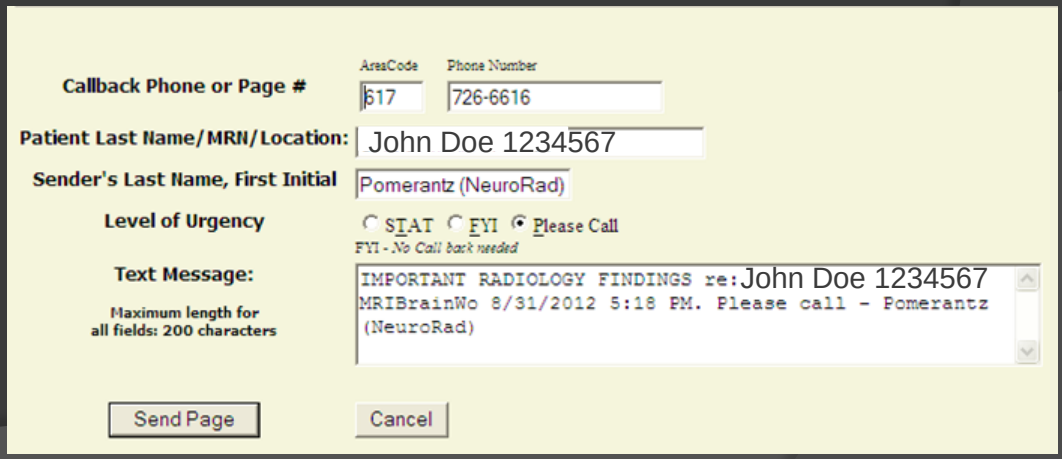
- LMR/QPID view for patient of study being dictated

1-Click Contextual Paging

- Extract context from current study
  - PACS or Open dictation report
- Page Appropriate Physician
  - Referring Clinician (outpatient)
  - Responding House Officer (EW or inpatient)
- Transmit both Radiologist and Patient Context
  - Who is Calling? - Radiologist Name/Service
  - Where? – Phone #
  - Calling About
    - Patient Name
    - MRN
    - Study Name & Date & Time



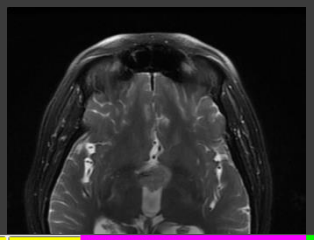


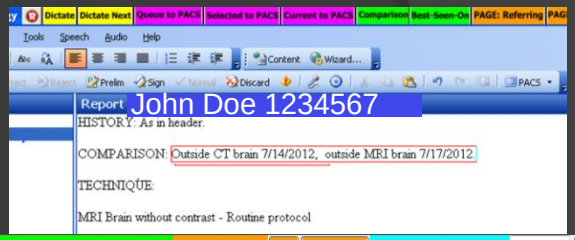


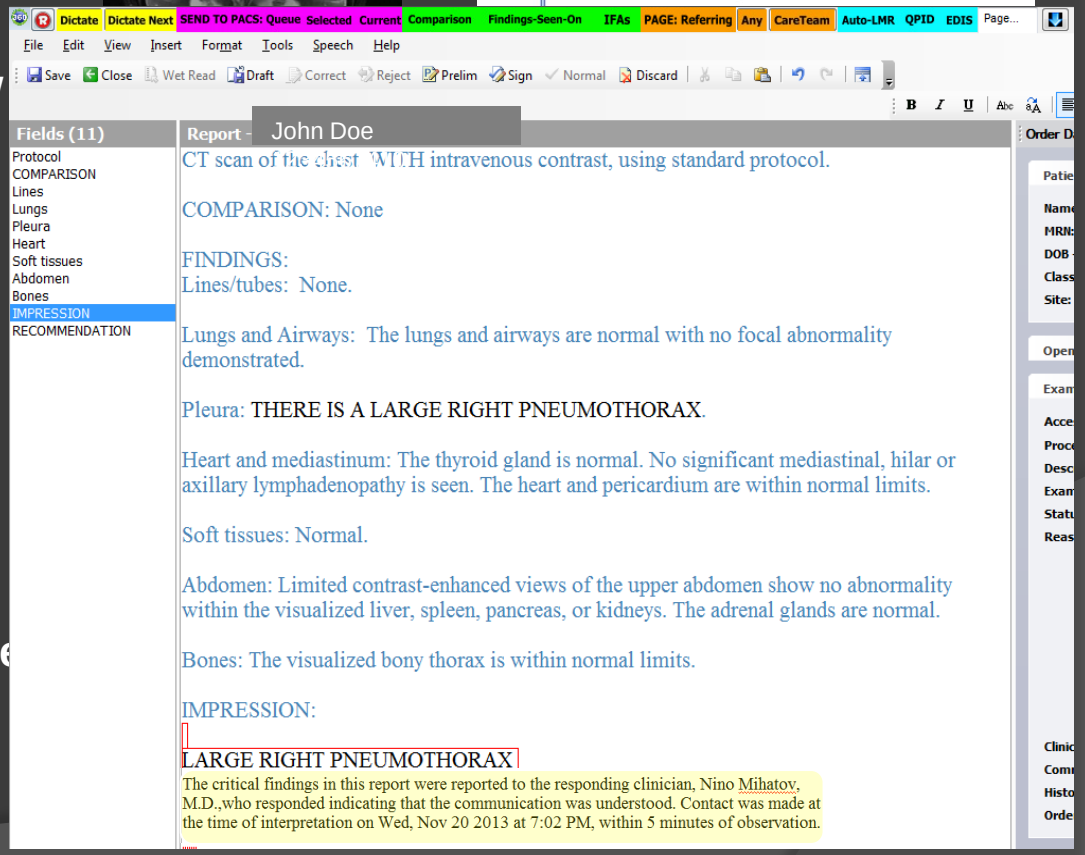
S Pomerantz, MGH

Example: 1-Click Contextual Critical Results Paging

- **Extract context from current study**
  - **PACS or Open dictation report**
- **Page Appropriate Physician**
  - **Referring Clinician (outpatient)**
  - **Responding House Officer (EW inpatient)**
- **Auto-insert Radiologist and Context**
  - **Who is Calling? - Radiologist Name/Service**
  - **Where? – Phone #**
  - **Calling About**
    - **Patient Name**
    - **MRN**
    - **Study Name & Date & Time**
- **Insert documentation into report automatically**





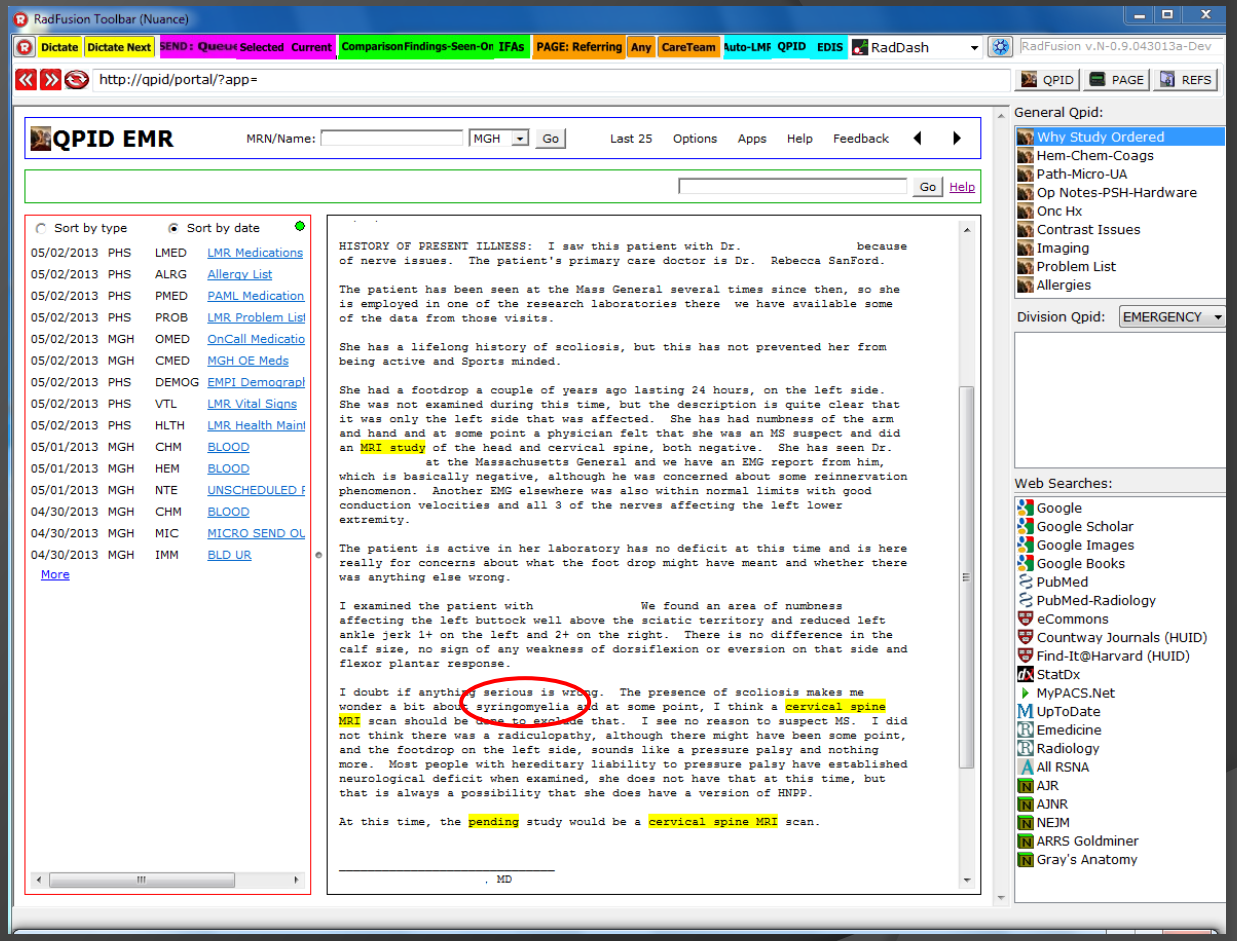


QUERY: WHY WAS STUDY ORDERED

EMR search:
Why was an MRI of the cervical spine ordered?

Search terms highlighted in text in EMR

Suspected syringomyelia quickly determined as reason for scan



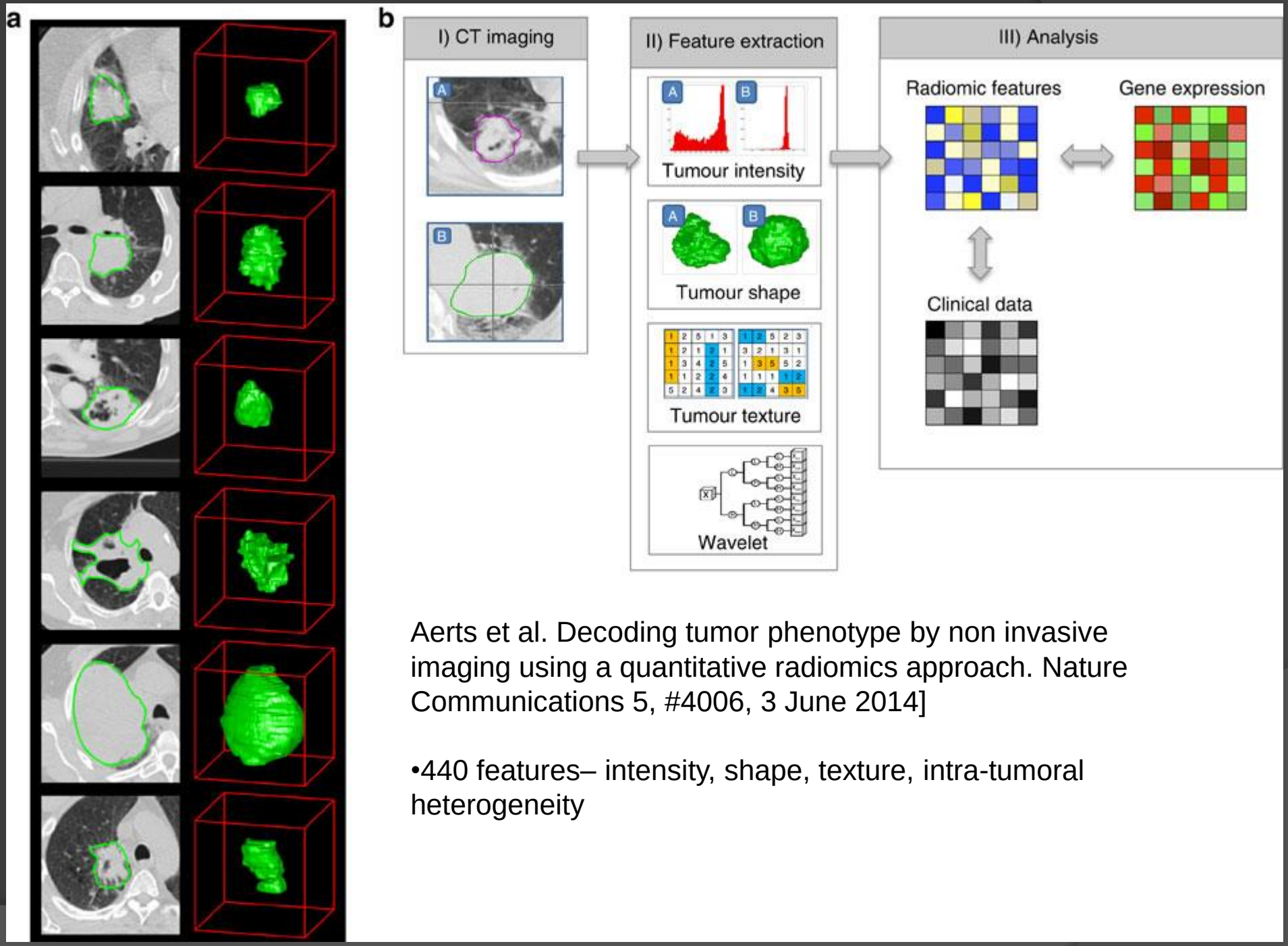
21st Century

Advanced Analytics

- Artificial Intelligence (AI) and Deep Learning (DL)
- Radiomics

Radiomics

- Mathematical interrogation of image data versus visual inspection
- Creation of mathematical “Phenotypes”
- Value comes from linking Radiomic patterns (Phenotypes) to diagnoses and prognoses in large populations of patients



Aerts et al. Decoding tumor phenotype by non invasive imaging using a quantitative radiomics approach. Nature Communications 5, #4006, 3 June 2014]

•440 features– intensity, shape, texture, intra-tumoral heterogeneity

> Radiology. 2016 Feb;278(2):563-77. doi: 10.1148/radiol.2015151169. Epub 2015 Nov 18.

Radiomics: Images Are More than Pictures, They Are Data

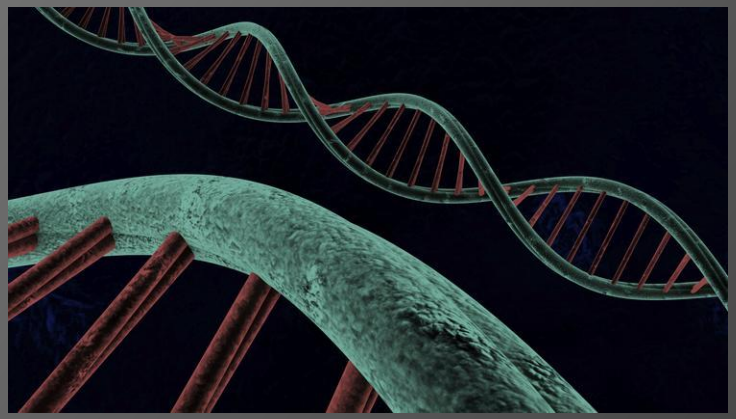
Robert J Gillies [1], Paul E Kinahan [1], Hedvig Hricak [1]

Review > Nat Rev Clin Oncol. 2017 Dec;14(12):749-762. doi: 10.1038/nrclinonc.2017.141. Epub 2017 Oct 4.

Radiomics: the bridge between medical imaging and personalized medicine

Review > Technol Cancer Res Treat. 2018 Jan 1;17:1533033818782788. doi: 10.1177/1533033818782788.

Radiomics for Response and Outcome Assessment for Non–Small Cell Lung Cancer



21st Century

Precision Medicine

Toward Precision Medicine: Building a Knowledge Network and A new Taxonomy of Disease

National Research Council of the National Academies, White Paper, 2011

"Classification of patients into subpopulations that differ in their susceptibility to a particular disease, in the biology and/or prognosis of those diseases, or in response to a specific treatment"

Subpopulations defined by genotype and phenotype

Imaging and Precision Medicine:

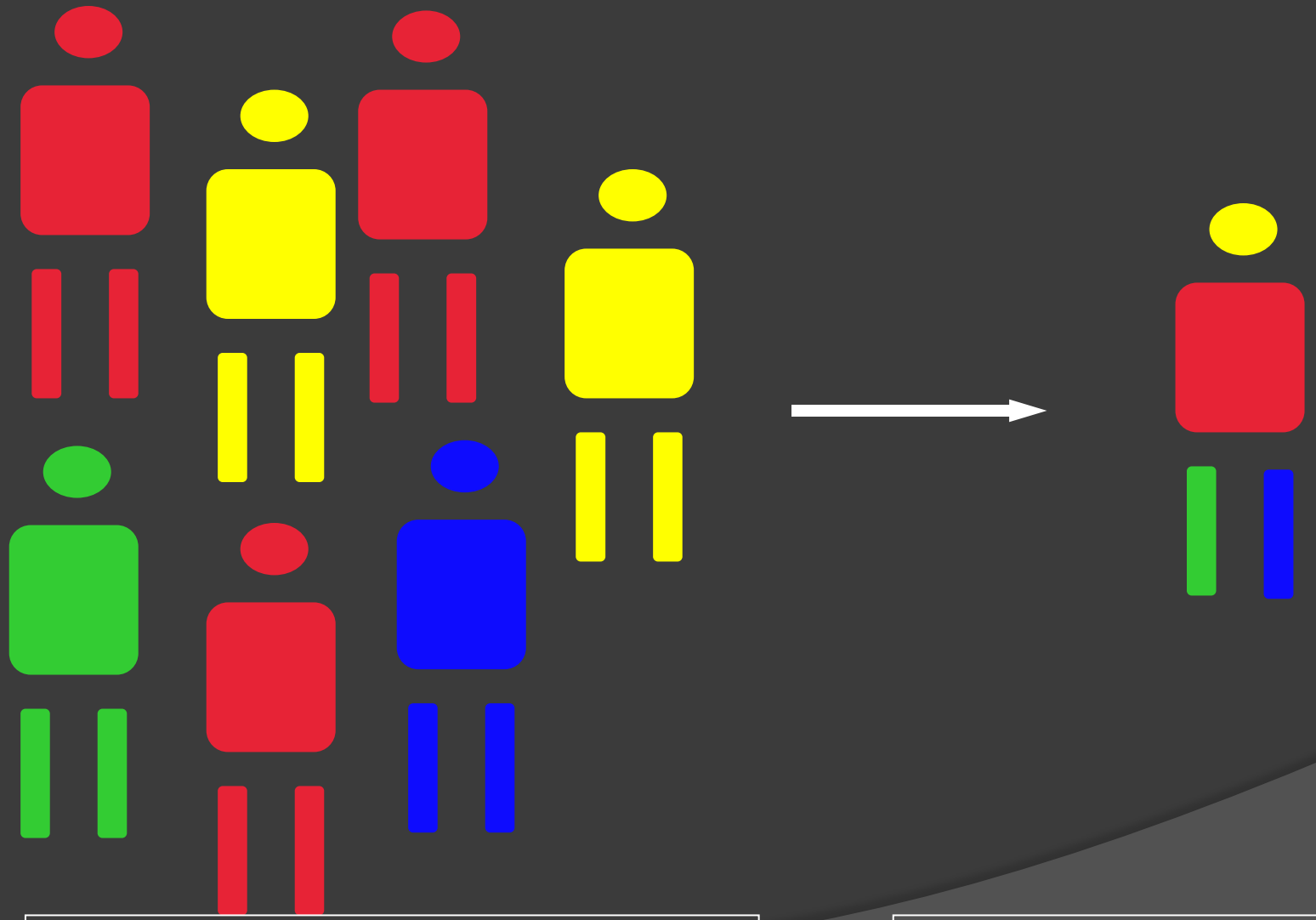
Phenotype: Observable manifestations of disease—clinical course, physical exam, labs, pathology, imaging

Imaging Phenotype: Sum total of the manifestations of a disease or condition demonstrable by imaging

ICD 10 and ICD 11: define ~ 99% of diseases based on phenotype even when genotype is known

Medical imaging and the practice of radiology are fundamentally exercises in determining disease phenotype

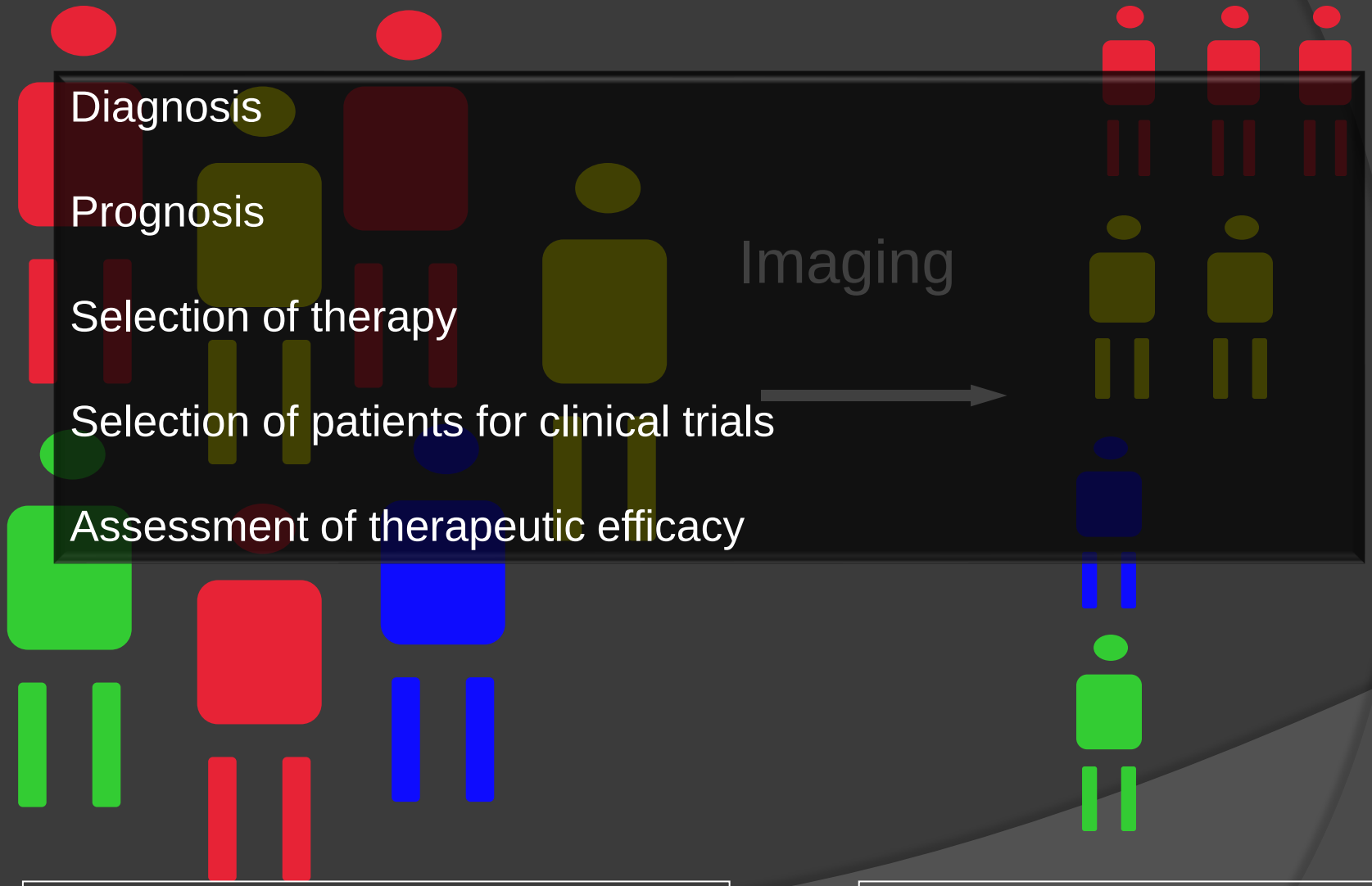
The Importance of adequate (sub) phenotype designation



Total Patient Population

“Average” Patient

The Importance of adequate (sub) phenotype designation



Total Patient Population

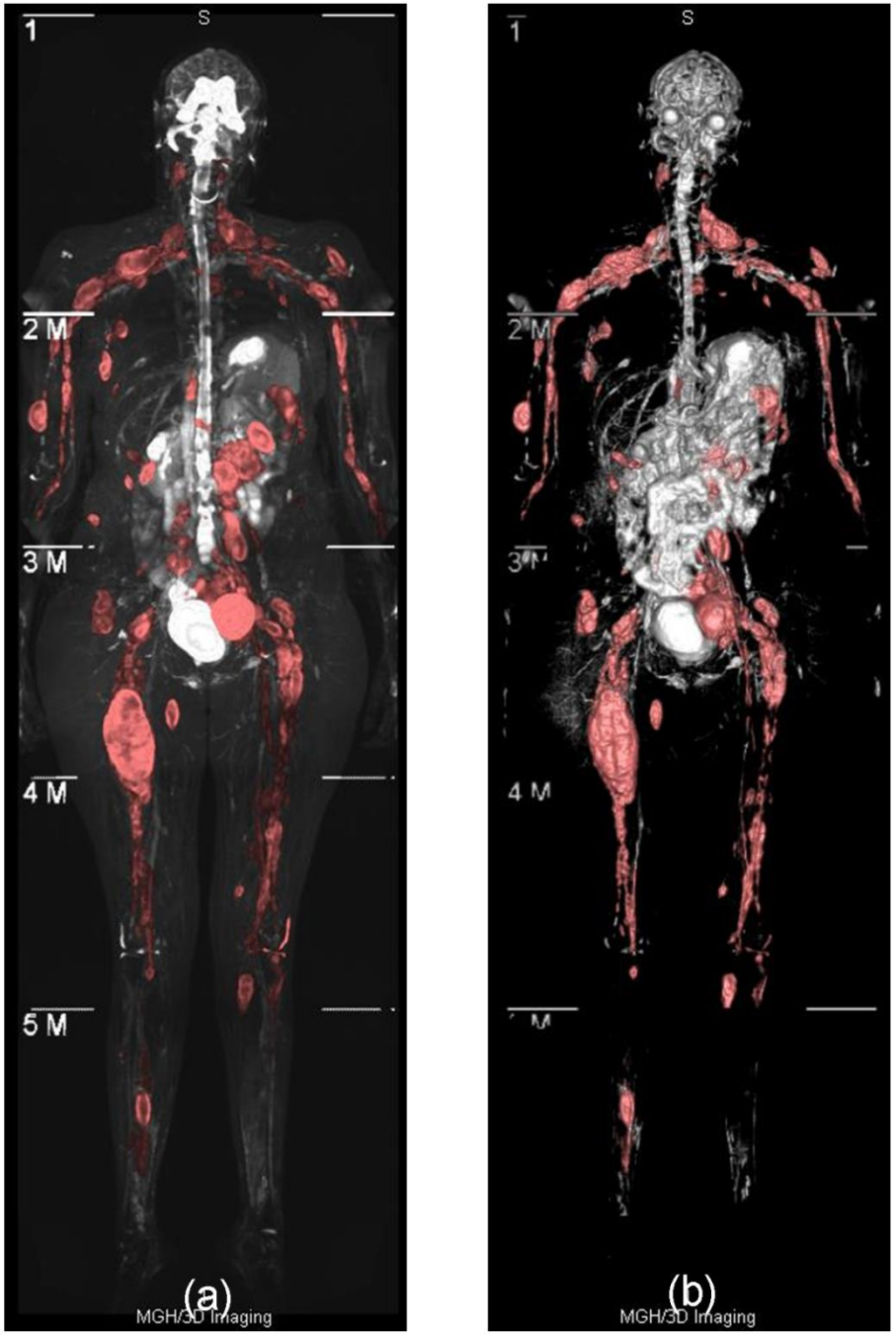
Sub populations

Neurofibromatosis 1

Genotype is known– but what is the expression of the condition—i.e. the phenotype?

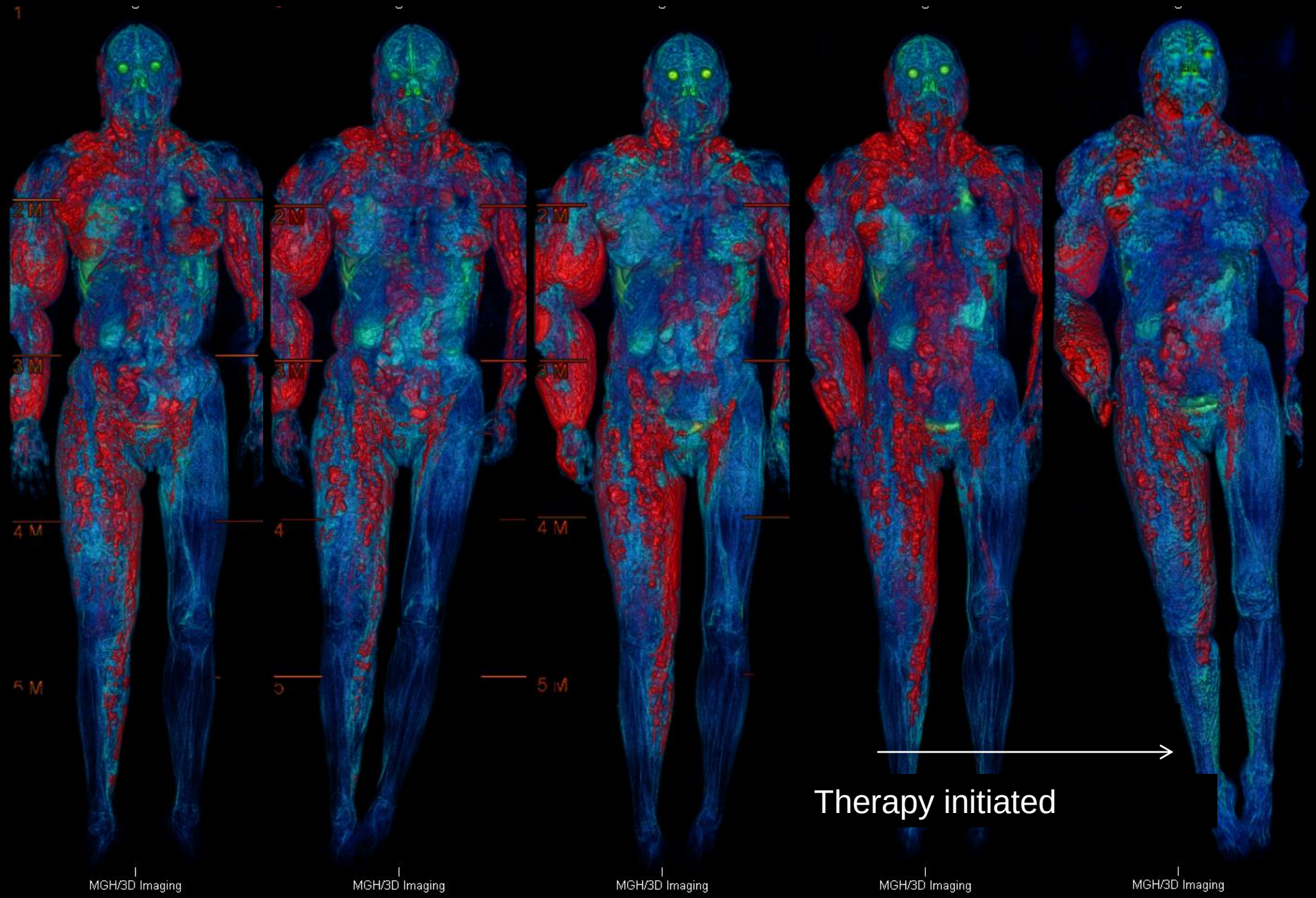
Imaging used for surveillance of disease manifestations:

- Presence
- Location
- Severity



Whole body MRI with image segmentation

Courtesy of WL Cai, MGH

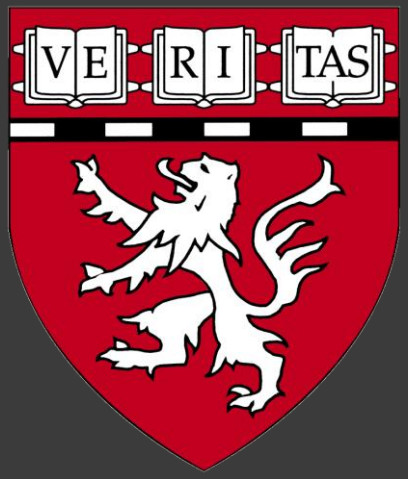


Courtesy of WL Cai, MGH

The Future

- Innovations in medical imaging will continue relentlessly in all aspects
- The pace of change is unlikely to slow down so enjoy the “slow” pace of change today

- But… our goals and commitments will not change:
  - Ever better more effective care and outcomes for our patients—live better longer
  - Better value for society
  - Higher career fulfillment and satisfaction for radiologists and other care givers


VE RI TAS


MGH
1811

“REINVENTING RADIOLOGY IN THE TWENTY-FIRST CENTURY”

Michigan Radiological Society: Centennial Gala and Education Event

October 23, 2021

James H Thrall MD

Chairman Emeritus

Department of Radiology

Massachusetts General Hospital

Distinguished Juan M Taveras Professor of Radiology

Harvard Medical School