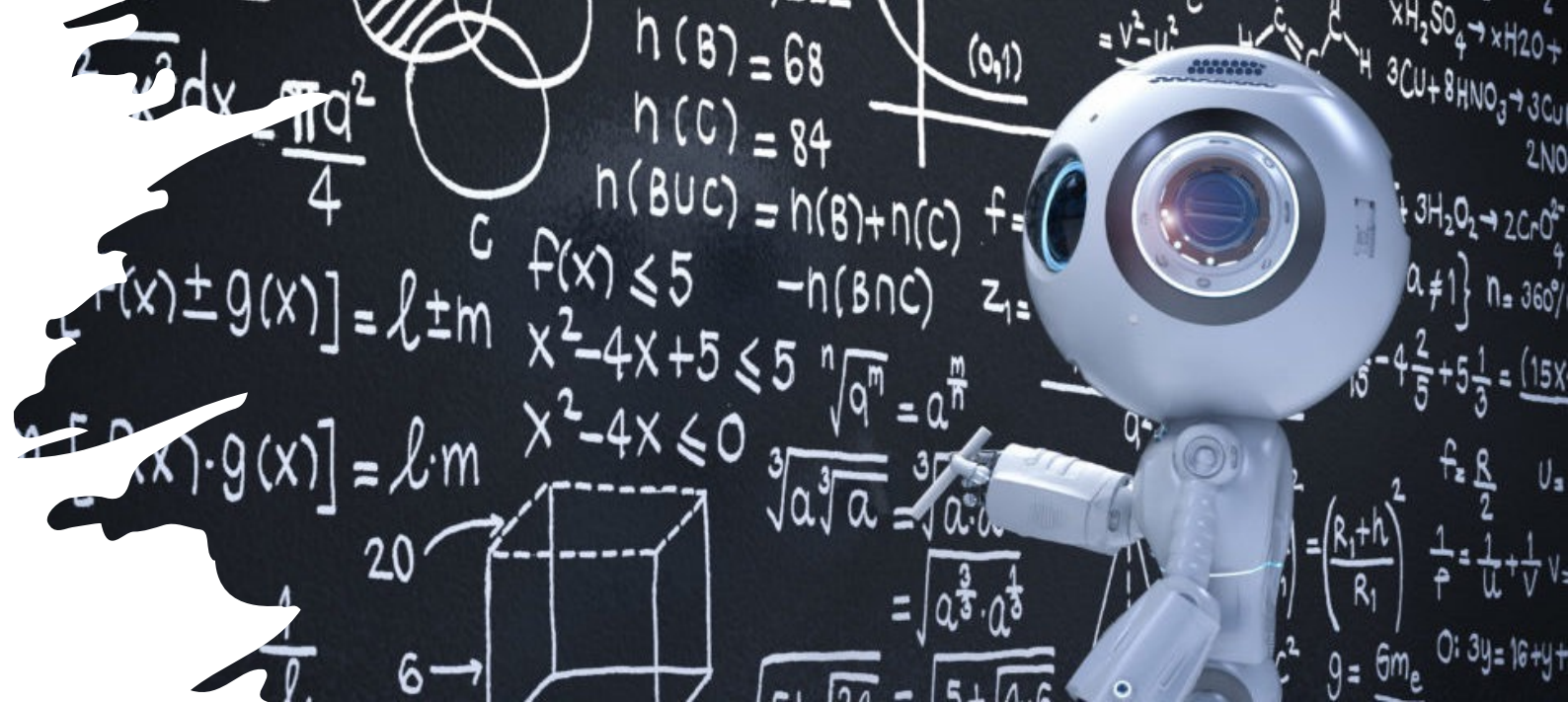


# Data Science in Radiology and Imaging Informatics

Tessa S. Cook, MD PhD CIIP FSIIM

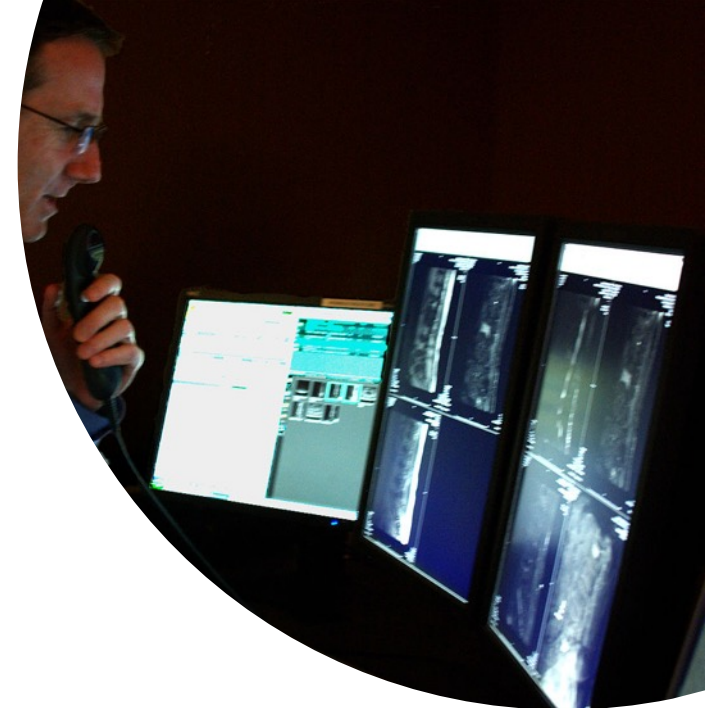
Penn Medicine

@asset25



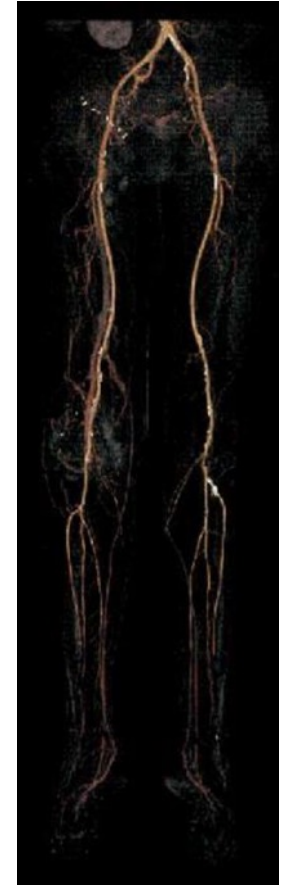
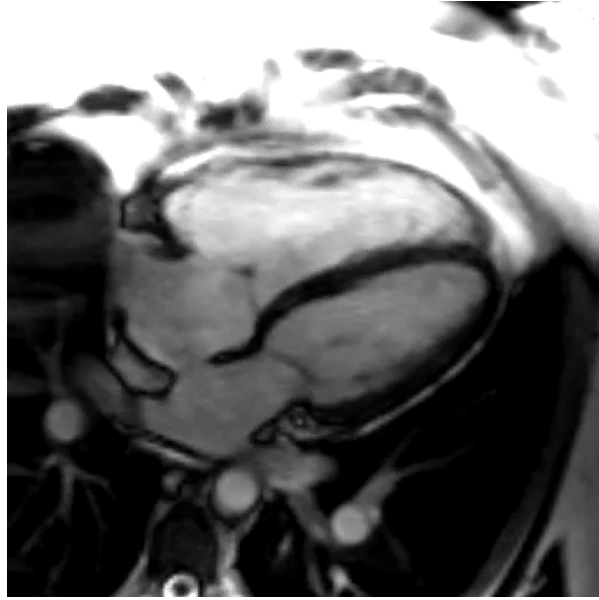
# Disclosures

- Board Member (SIIM, AUR)
- Director, National Imaging Informatics Course
- Member, Program Committee (RSNA, AUR)
- Member, RSNA Research and Development Committee
- Member, ACR Informatics Commission
- Fellowship Director, Imaging Informatics, Penn Radiology
- Grant funding from RSNA, ACR, NIH
- Departmental AI vendor agreements



# A Day in the Life of a Radiologist





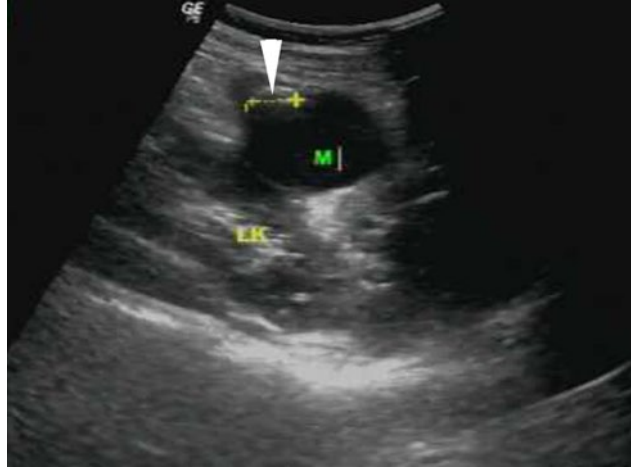
# A Day in the Life of a Cardiovascular Radiologist



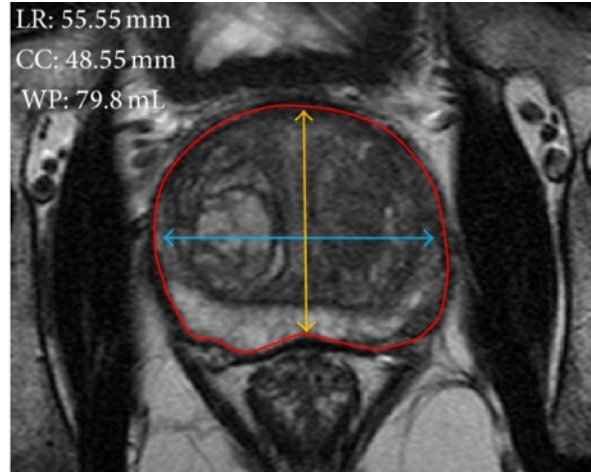


# Why Radiology Needs Data Science

Dose Report			
Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
Scout	-	-	-
Helical	I184.500-I184.500	13.87	44.28
Helical	I83.250-I333.250	18.29	511.50
Total Exam DLP:			555.78
1/1			



# Why Radiology Needs Data Science



- Clinical practice → large amounts of data

## • Types

- Images
- Reports
- Measurements
- Interval change
- ...more

PATIENT NAME: \_\_\_\_\_ M  F   
 DATE OF BIRTH: \_\_\_\_\_ PATIENT NUMBER: \_\_\_\_\_  
 DATE OF STUDY: \_\_\_\_\_

MEDICAL HISTORY: \_\_\_\_\_  
 RISK FACTORS: \_\_\_\_\_  
 INDICATION FOR THE STUDY: \_\_\_\_\_

IMAGING TECHNIQUE: \_\_\_\_\_  
 COMPARISON STUDY: DATE \_\_\_\_\_ DETAILS \_\_\_\_\_

LIMITATIONS OF THE STUDY: \_\_\_\_\_

FINDINGS

Presence of dilated bile ducts:  
 Yes  No   
 If yes:  
 Mild  Moderate  Severe

Measurements:  
 CBD: \_\_\_\_\_ mm Main IHBD - R: \_\_\_\_\_ mm L: \_\_\_\_\_ mm  
 GB - length: \_\_\_\_\_ mm wall thickness: \_\_\_\_\_ mm  
 Pancreatic duct: \_\_\_\_\_ mm

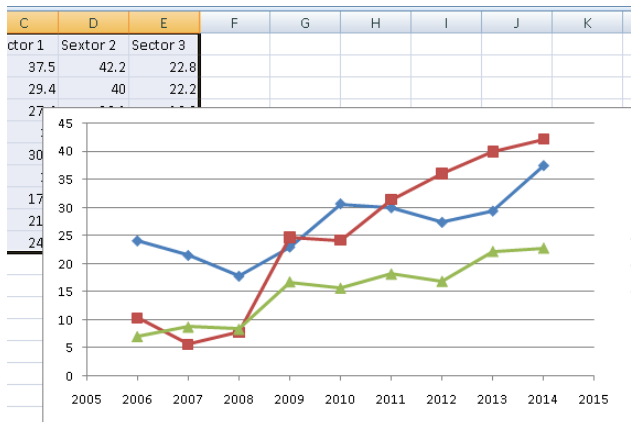
Level of obstruction:  
 Hilar  Supra-pancreatic  Intra-pancreatic

Transitional zone:  
 Smooth tapered narrowing  Abrupt cut off

Presence of echogenic nodule or calculus  Number: \_\_\_\_\_ Measurement: \_\_\_\_\_ mm

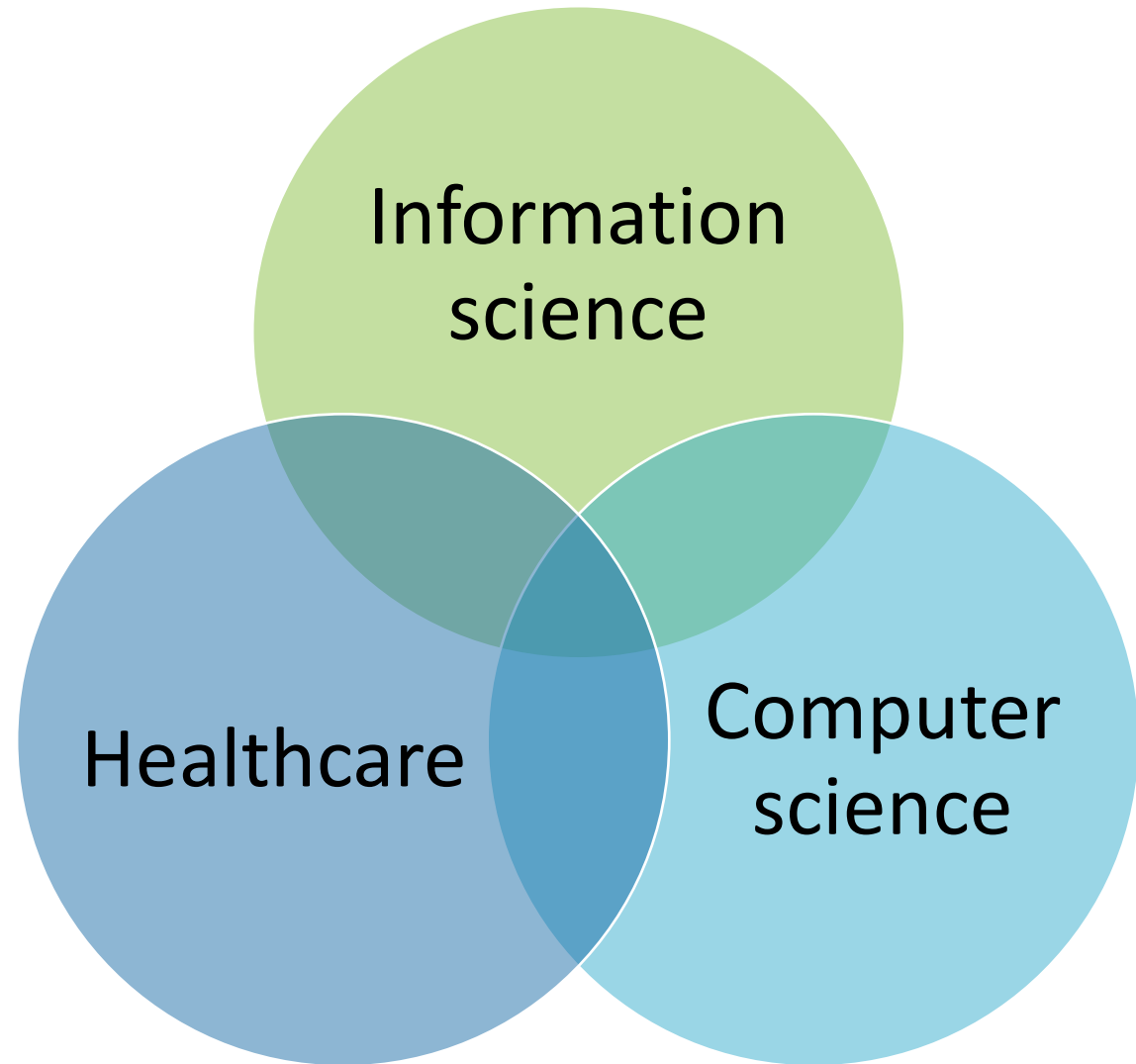
Additional information:  
 Liver: \_\_\_\_\_  
 Spleen: \_\_\_\_\_  
 Pancreas: \_\_\_\_\_  
 Kidneys: \_\_\_\_\_  
 Gallbladder: \_\_\_\_\_  
 Lymphadenopathy: \_\_\_\_\_  
 Aortic: \_\_\_\_\_

Assessment:  
 Cause of obstruction - Benign  Malignant



- Where does the data go?

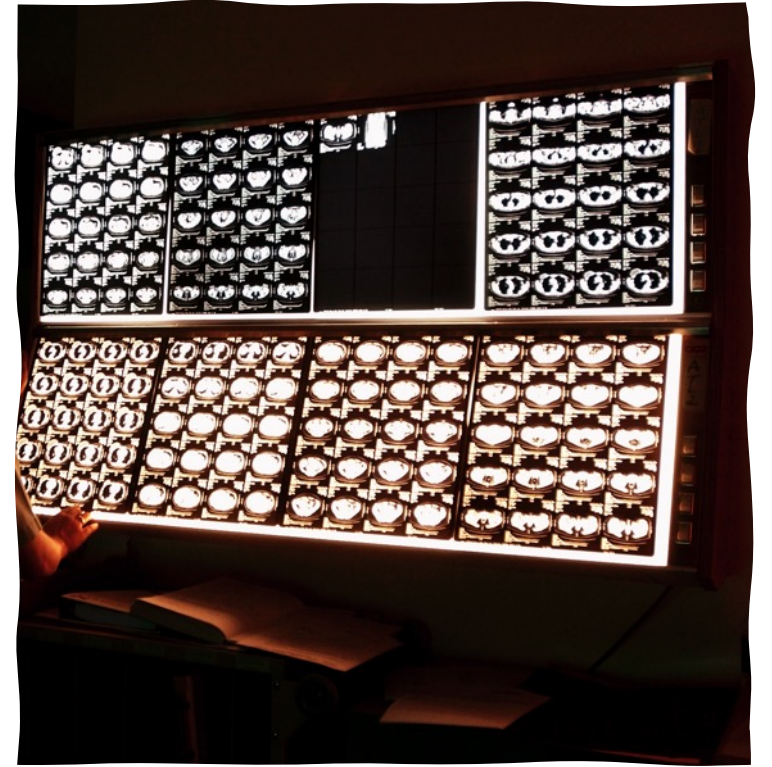
# Imaging Informatics





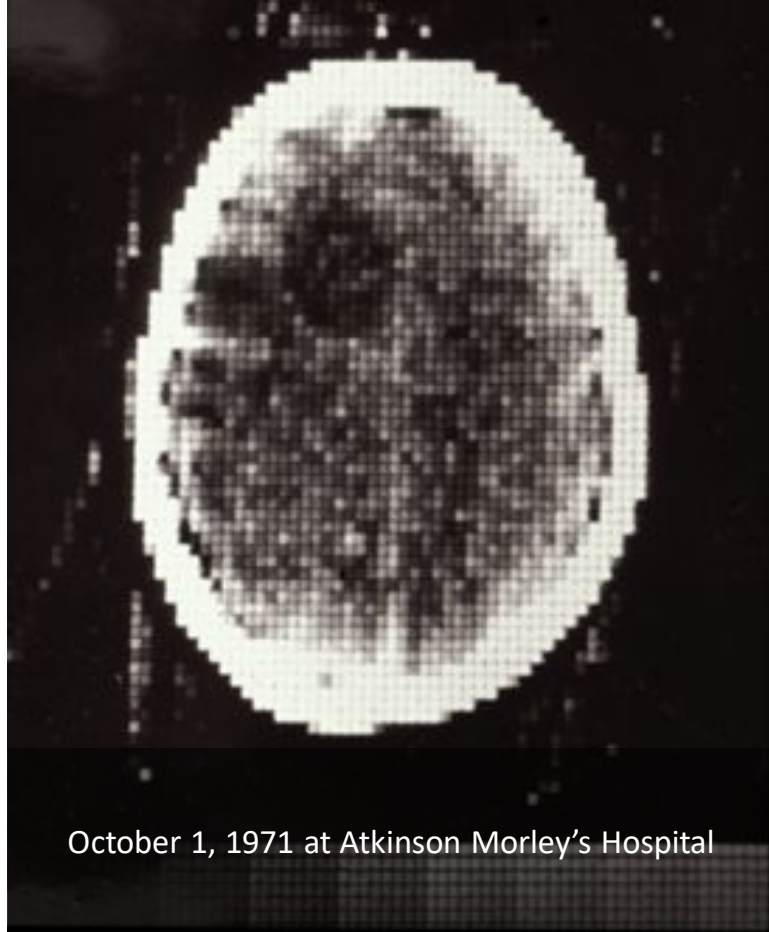
# The Origins of Imaging Informatics





# Radiology, pre-1970

# The First Head CT





# The Origin of Imaging Informatics



APPLICATIONS OF PICTURE PROCESSING, IMAGE ANALYSIS AND  
COMPUTER GRAPHICS TECHNIQUES TO CRANIAL CT SCANS

H.U.Lemke, H.S.Stiehl, H.Scharnweber, D.Jackél

COMPACT Project Group, Institut für Technische Informatik,  
Technische Universität Berlin

Further thought is also given to the framework in which CT processing may take place. To ensure clinical efficacy a concept of a Medical Work Station as part of a distributed computing network is discussed. Some consideration is then given to the physicians possible working modes within such a system.

part of a distributed computing network is discussed. Some consideration is then given to the physicians possible working modes within such a system.

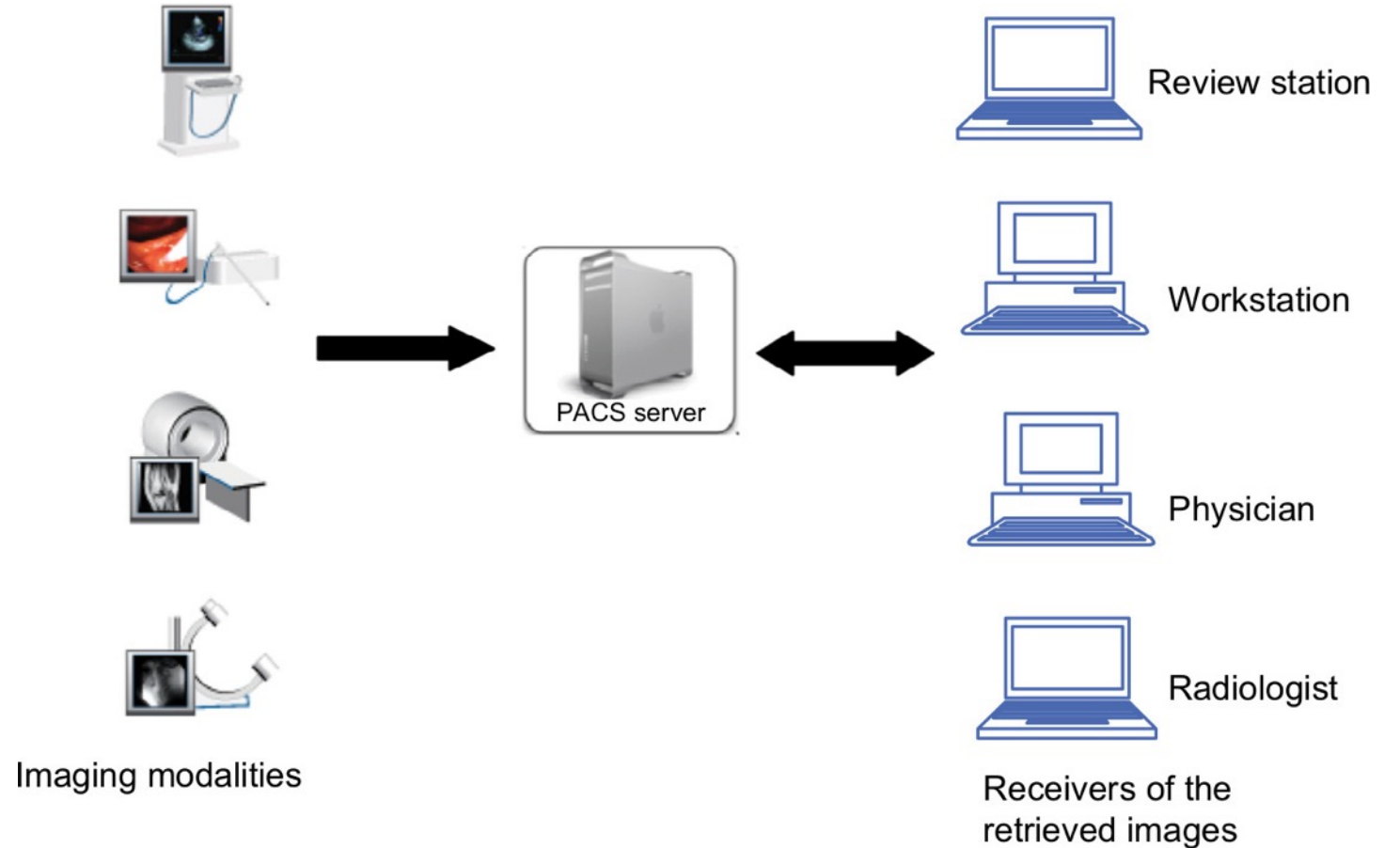
all modes of communication and voice communication).

paper that each of the above station management and evaluation is satisfied by using medical a distributed computing

system is currently being Institut für Technische Informatik, Technische Universität Berlin. The prin-

cipal application of the MWS's is for the management of neurological disorders and includes a system for the Computerized Management, Processing and Analysis of Computed Tomograms (COMPACT).

# PACS: Picture Archiving and Communications System









# Data Science and Imaging Informatics in Practice

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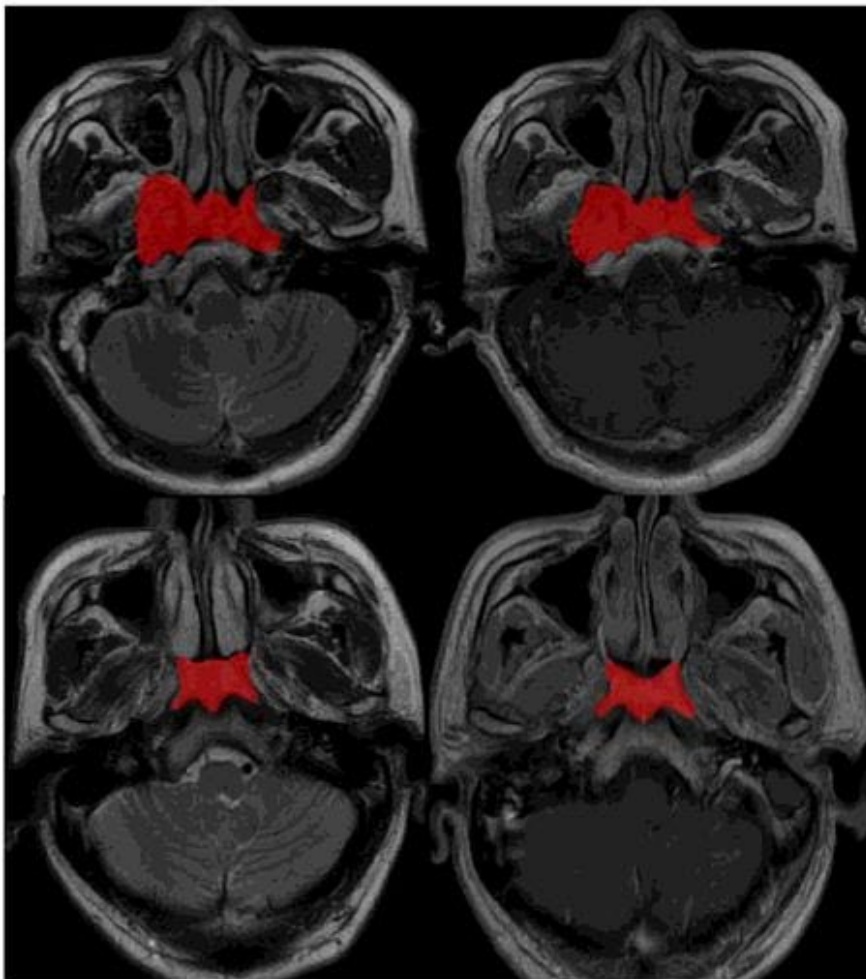




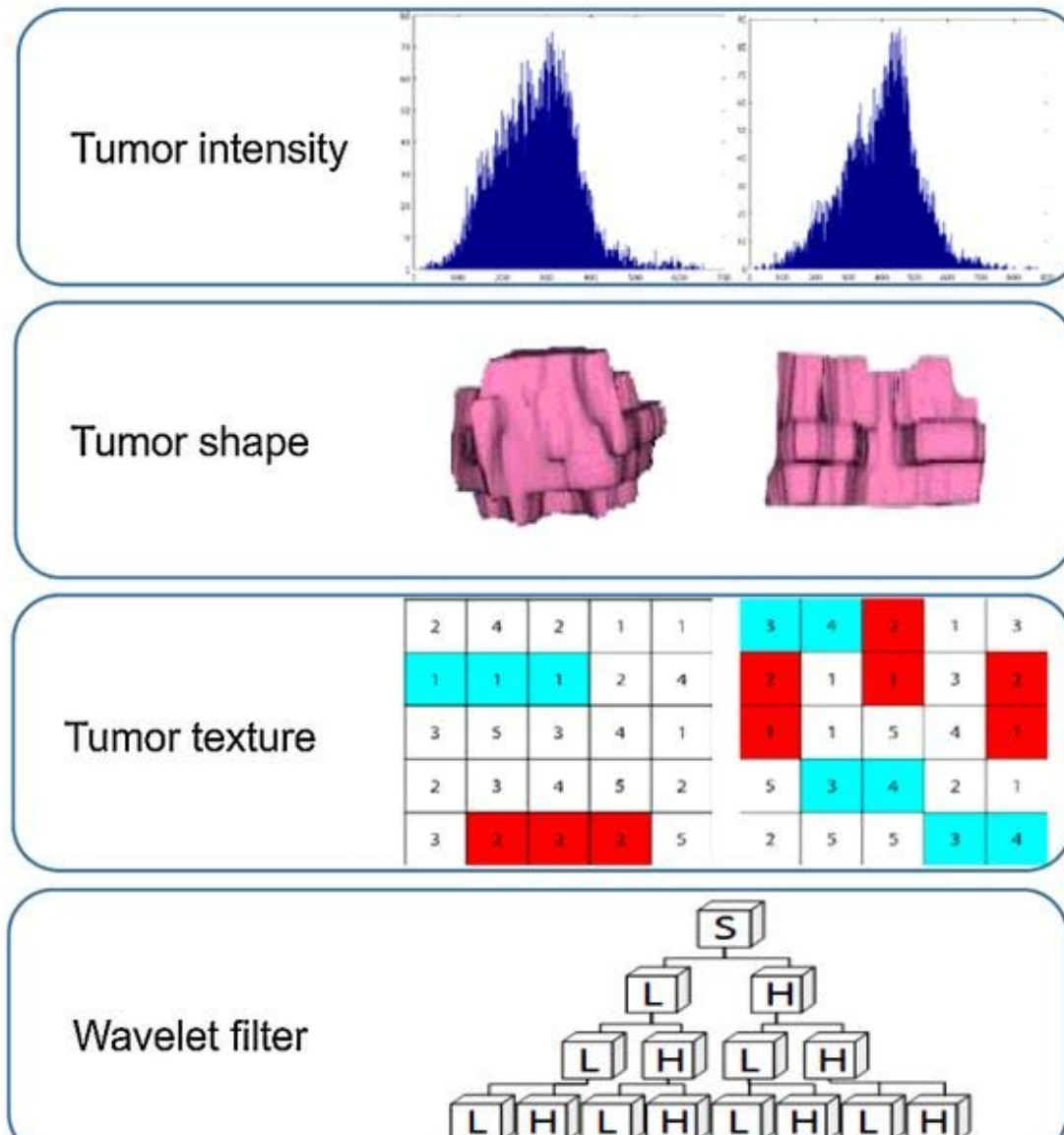


**A**

MRI images

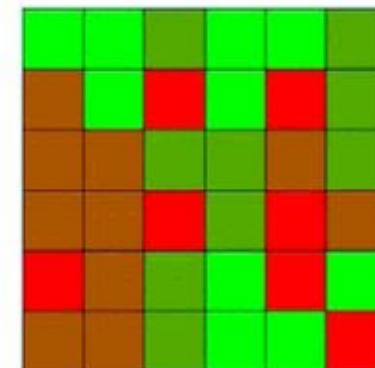
**B**

Feature extraction

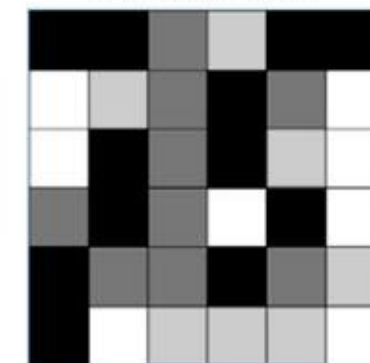
**C**

Analysis

Radiomic features



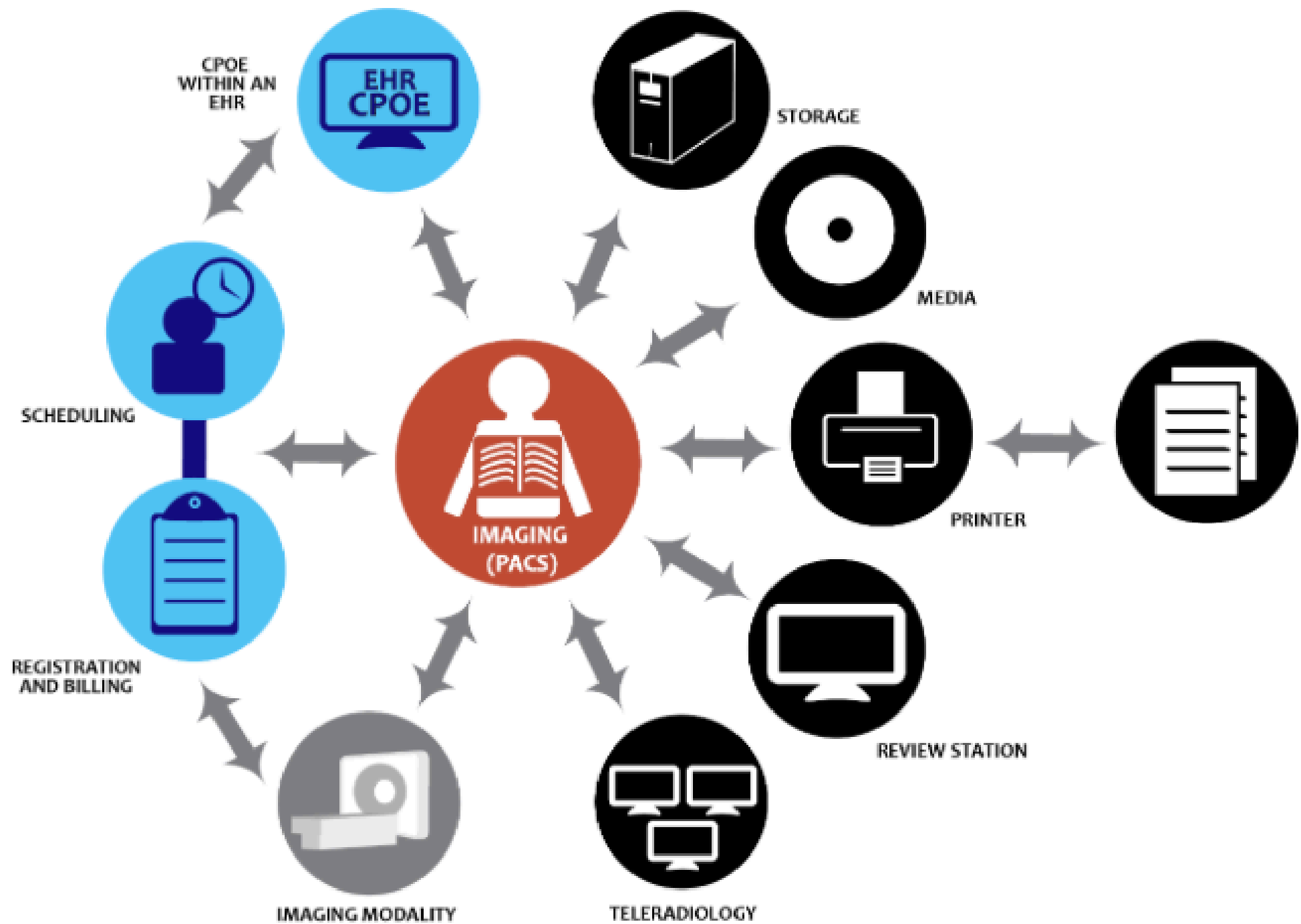
Clinical data

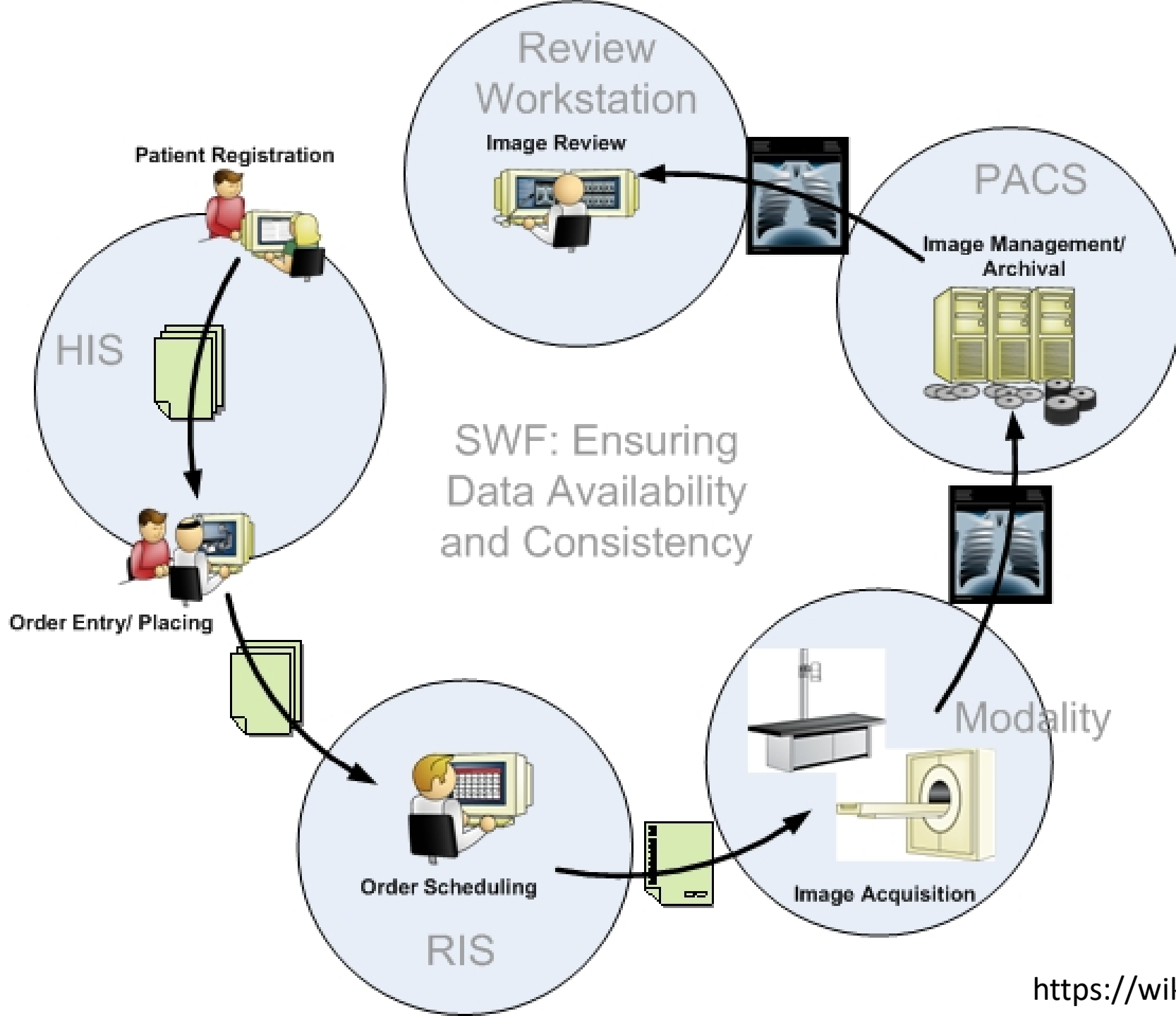


**Clinical Cancer Research**

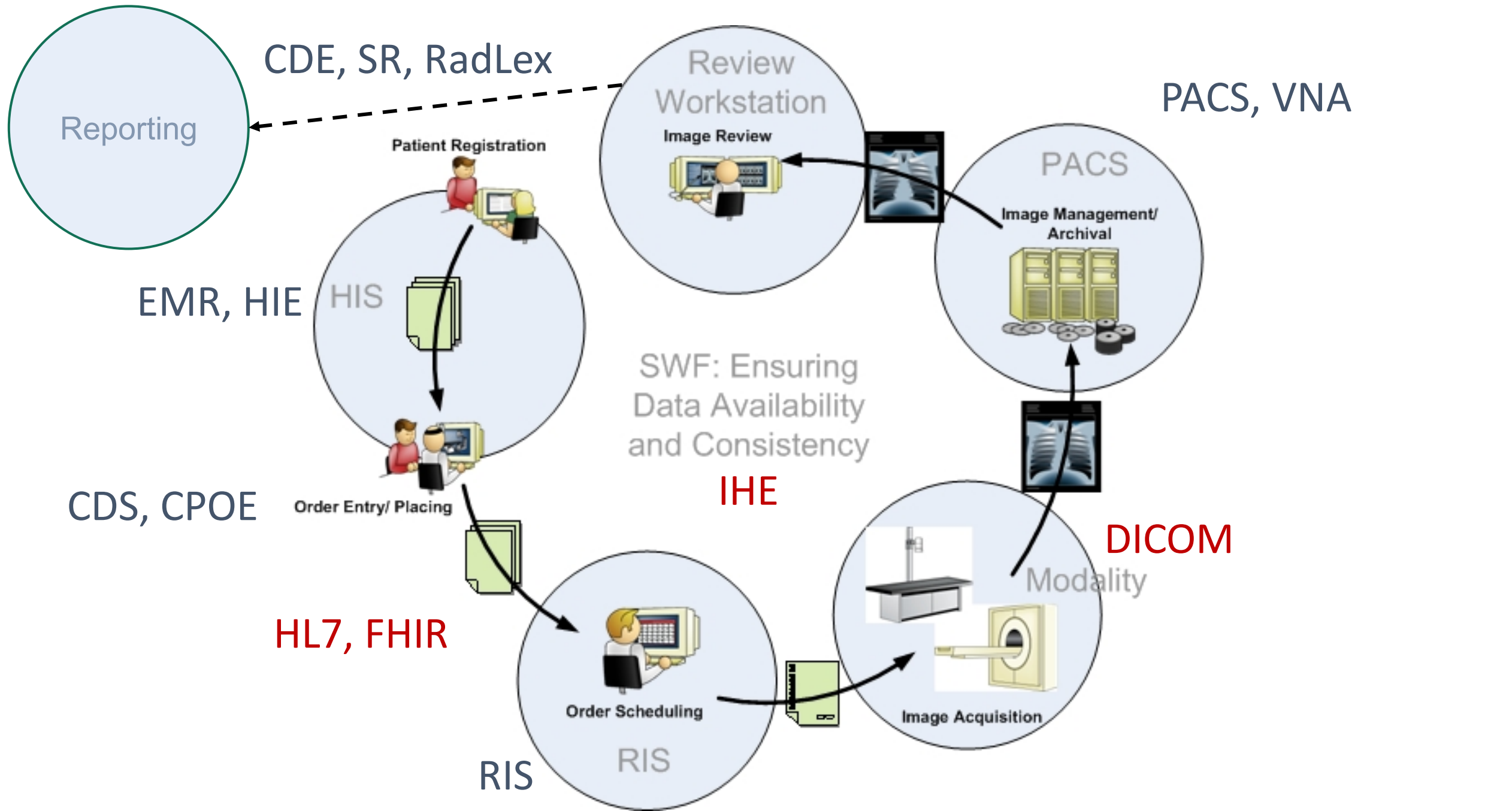
AACR American Association for Cancer Research







# Early Radiology Workflow



# Standards





# Standards in Radiology

<https://www.ihe.net>



<https://www.dicomstandard.org>



<http://hl7.org/>



<http://hl7.org/fhir>

# HOW STANDARDS PROLIFERATE:

(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)

SITUATION:  
THERE ARE  
14 COMPETING  
STANDARDS.

14?! RIDICULOUS!  
WE NEED TO DEVELOP  
ONE UNIVERSAL STANDARD  
THAT COVERS EVERYONE'S  
USE CASES.



SOON:

SITUATION:  
THERE ARE  
15 COMPETING  
STANDARDS.

<b>IHE Domains</b>
Cardiology
Dental
Eye Care
IT Infrastructure
Pathology and Laboratory Medicine
Patient Care Coordination
Devices
Pharmacy
Quality, Research and Public Health
Radiation Oncology
<b>Radiology</b>

## Radiology

[Technical Framework](#) | [Public Comment](#) | [Wiki Page](#)

IHE Radiology was formed in 1998 to address issues of interoperability and information sharing that impact the quality of care in medical imaging. It has developed and documented standards-based solutions to these problems and organized testing and education to foster their adoption. IHE solutions are now available in hundreds of commercial radiology-related information systems and are implemented in care sites around the world.

IHE Radiology is sponsored by the [Radiological Society of North America](#).

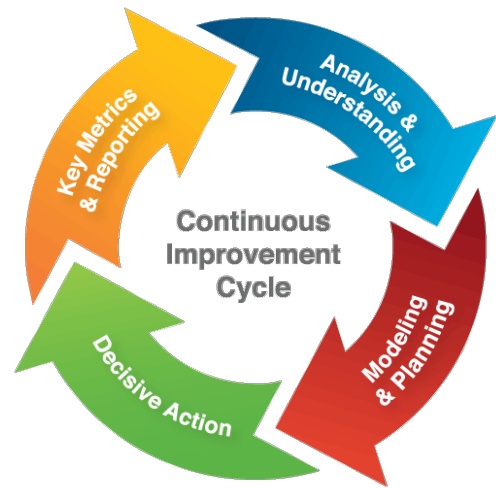
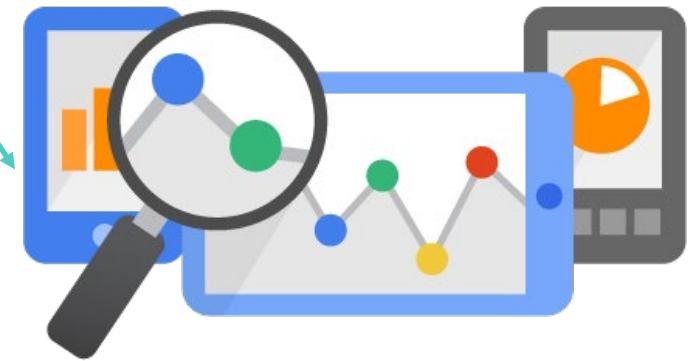
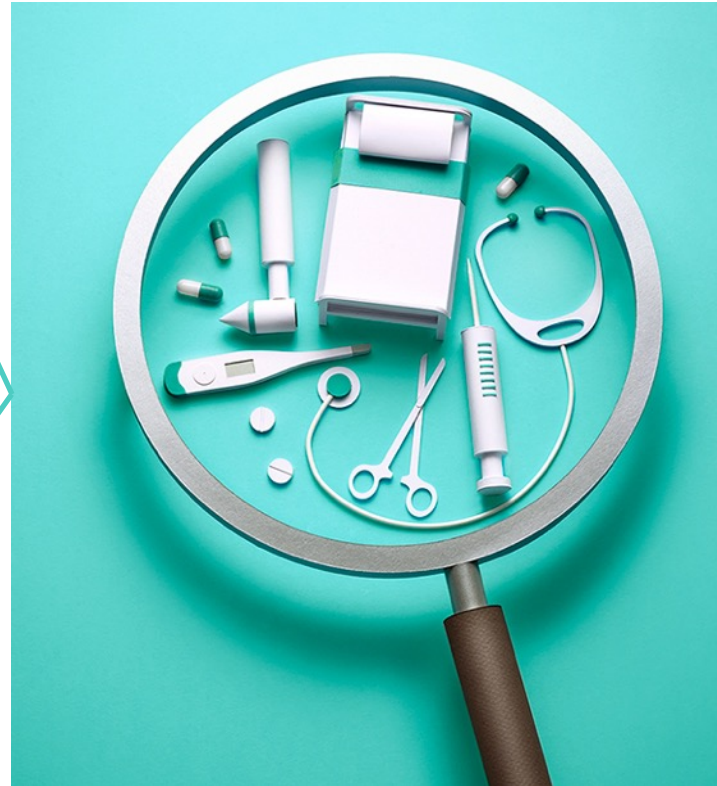
### Radiology Profiles

IHE Radiology integration profiles are specified in detail in the [IHE Radiology Technical Framework](#). These profiles include:

#### Profiles for Workflow

- [SWF] **Scheduled Workflow** integrates ordering, scheduling, imaging acquisition, storage and viewing for Radiology exams.
- [PIR] **Patient Information Reconciliation** coordinates reconciliation of the patient record when images are acquired for unidentified (e.g. trauma), or misidentified patients.

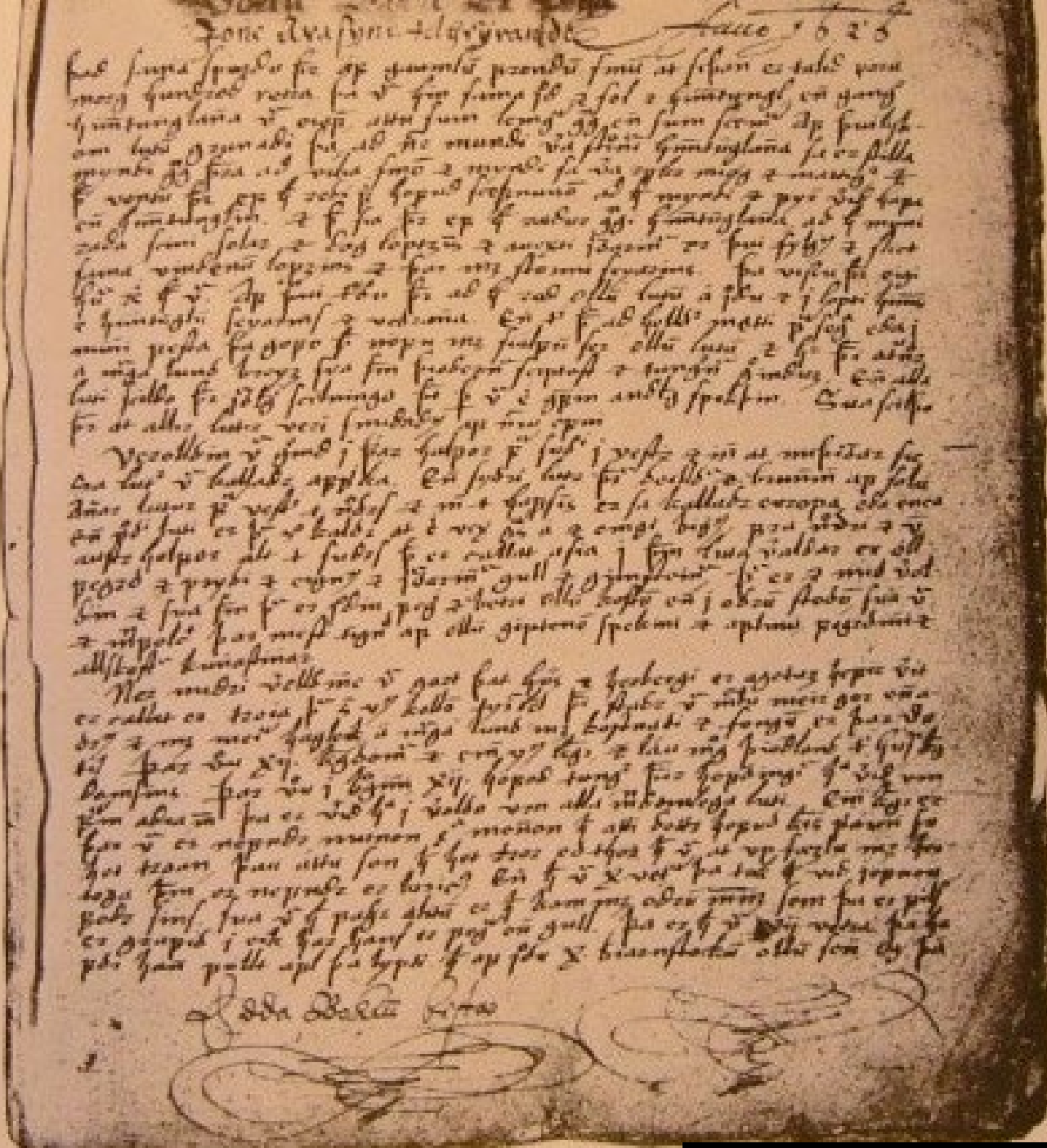
# Interoperability of Healthcare Systems





# Data Mining Challenges

- Different data sources
- Systems not communicating
- Obscure schema
- Structured vs. unstructured data



# Adding Structure

## **RadLex radiology lexicon**

---

We recognize the benefits that come from radiologists using common language to communicate diagnostic results. For this reason, RSNA produced [RadLex®](#), a comprehensive set of radiology terms for use in radiology reporting, decision support, data mining, data registries, education and research.

RadLex provides the foundation for vital data resources used in radiology:

- [The LOINC/RSNA Radiology Playbook](#)
- [RadElement Common Data Elements](#)
- [RadReport Radiology Reporting Templates](#)

<http://radlex.org>

# RadReport Template Library


Structured templates for clear and consistent reports.

## Osseous Structures and Chest Wall:

No pathologic osseous or soft-tissue process is present.

No actionable nodule is present in the imaged portions of the thyroid lobes.

## Lower Neck:

Upper Abdomen: No pathological process is present in the imaged portion of the upper abdomen. 

None.

## Additional Findings:

Acute pulmonary embolism is present. Emboli are present in segmental and more proximal arteries.

No acute pulmonary embolism is present.

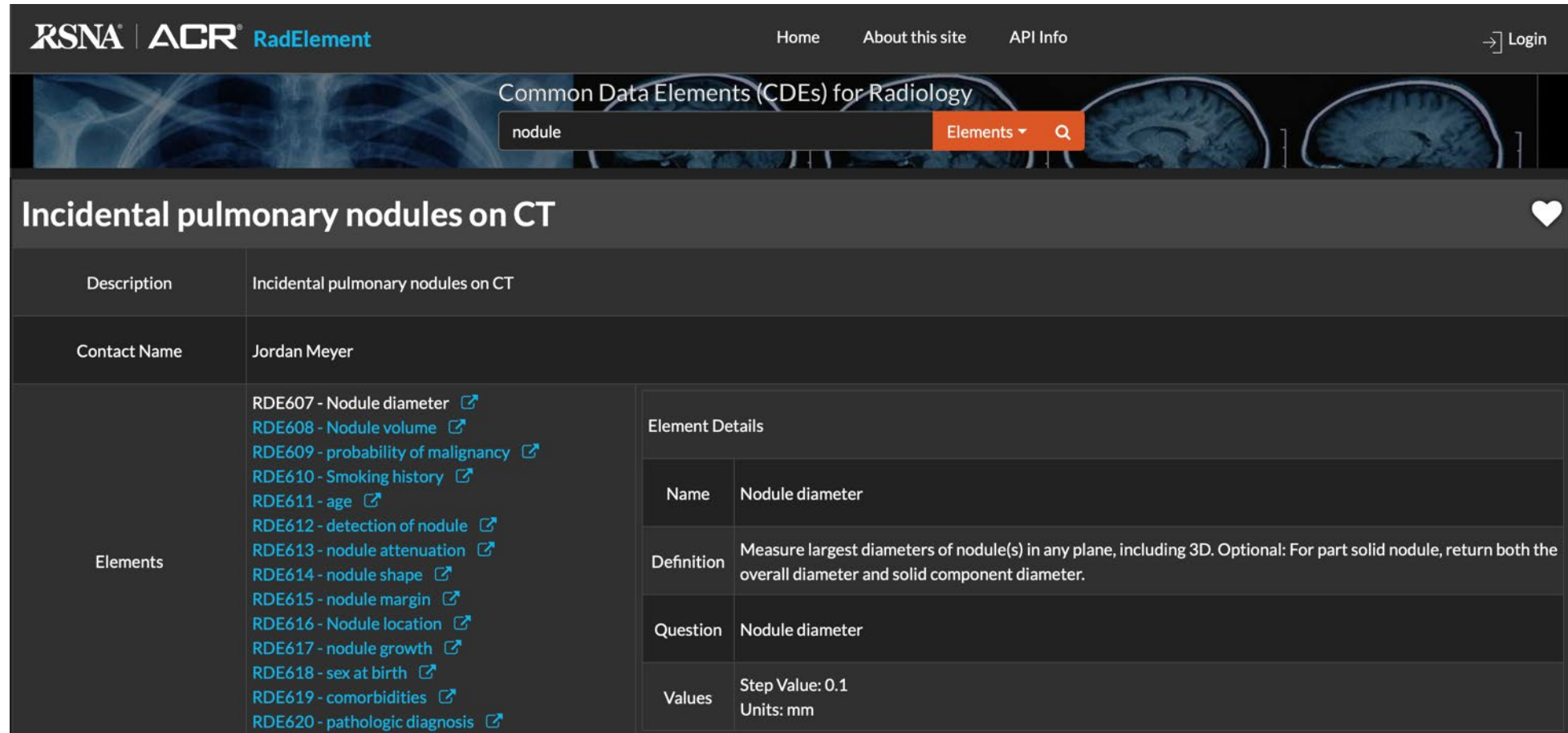
Acute pulmonary embolism is present. Emboli are confined to subsegmental arteries.

# Structured Reporting

<https://radreport.org/>



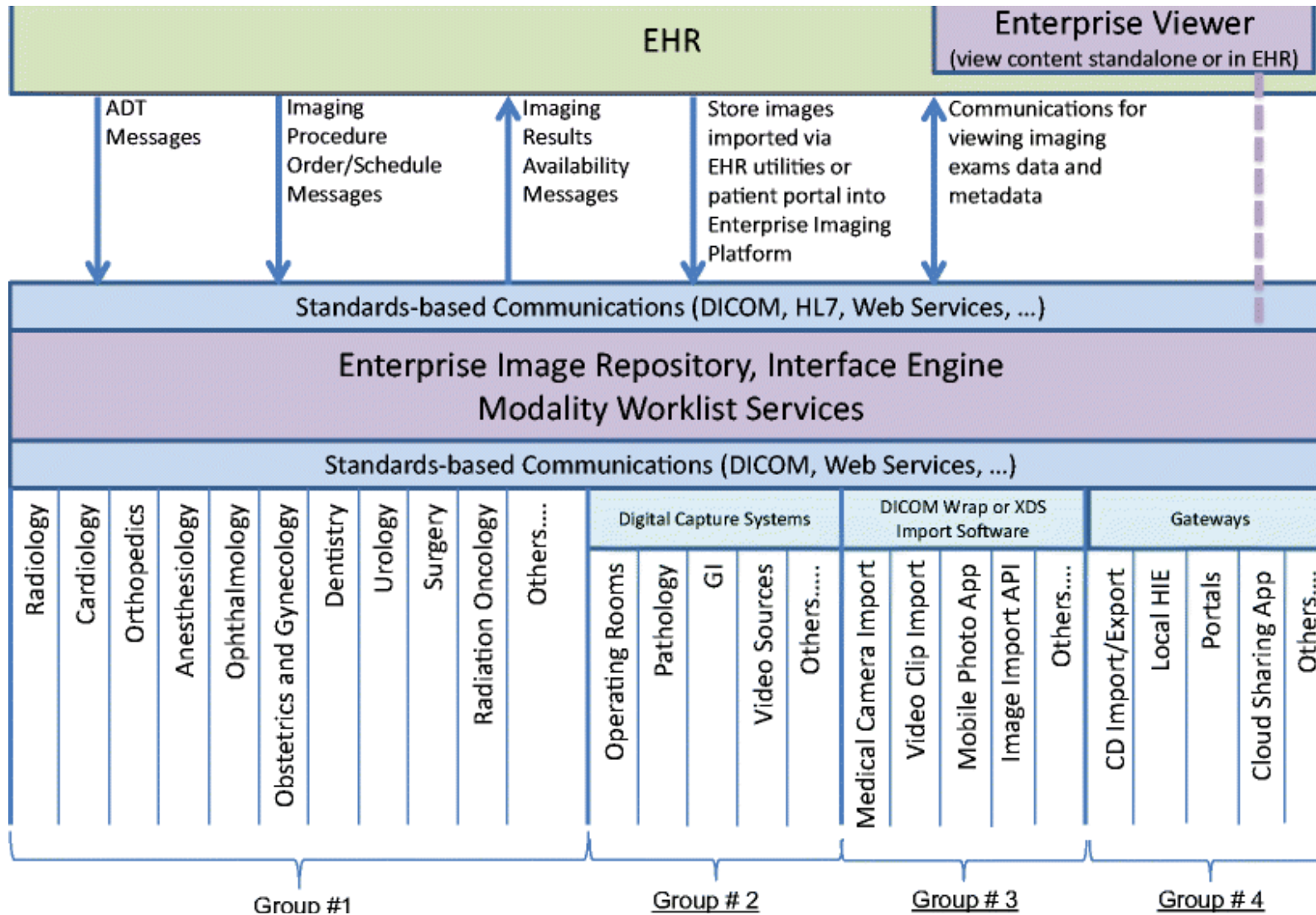
# Common Data Elements



The screenshot shows the RSNACR RadElement website interface. At the top, there is a navigation bar with links for Home, About this site, and API Info, along with a Login button. Below the navigation bar is a header section with the title "Common Data Elements (CDEs) for Radiology" and a search bar containing the word "nodule". The search results are displayed in a table format.

Incidental pulmonary nodules on CT										
Description	Incidental pulmonary nodules on CT									
Contact Name	Jordan Meyer									
Elements	<ul style="list-style-type: none"><li>RDE607 - Nodule diameter</li><li>RDE608 - Nodule volume</li><li>RDE609 - probability of malignancy</li><li>RDE610 - Smoking history</li><li>RDE611 - age</li><li>RDE612 - detection of nodule</li><li>RDE613 - nodule attenuation</li><li>RDE614 - nodule shape</li><li>RDE615 - nodule margin</li><li>RDE616 - Nodule location</li><li>RDE617 - nodule growth</li><li>RDE618 - sex at birth</li><li>RDE619 - comorbidities</li><li>RDE620 - pathologic diagnosis</li></ul>									
	<table border="1"><thead><tr><th colspan="2">Element Details</th></tr></thead><tbody><tr><td>Name</td><td>Nodule diameter</td></tr><tr><td>Definition</td><td>Measure largest diameters of nodule(s) in any plane, including 3D. Optional: For part solid nodule, return both the overall diameter and solid component diameter.</td></tr><tr><td>Question</td><td>Nodule diameter</td></tr><tr><td>Values</td><td>Step Value: 0.1 Units: mm</td></tr></tbody></table>	Element Details		Name	Nodule diameter	Definition	Measure largest diameters of nodule(s) in any plane, including 3D. Optional: For part solid nodule, return both the overall diameter and solid component diameter.	Question	Nodule diameter	Values
Element Details										
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Question	Nodule diameter									
Values	Step Value: 0.1 Units: mm									

<https://radelement.org/>



# Enterprise Imaging

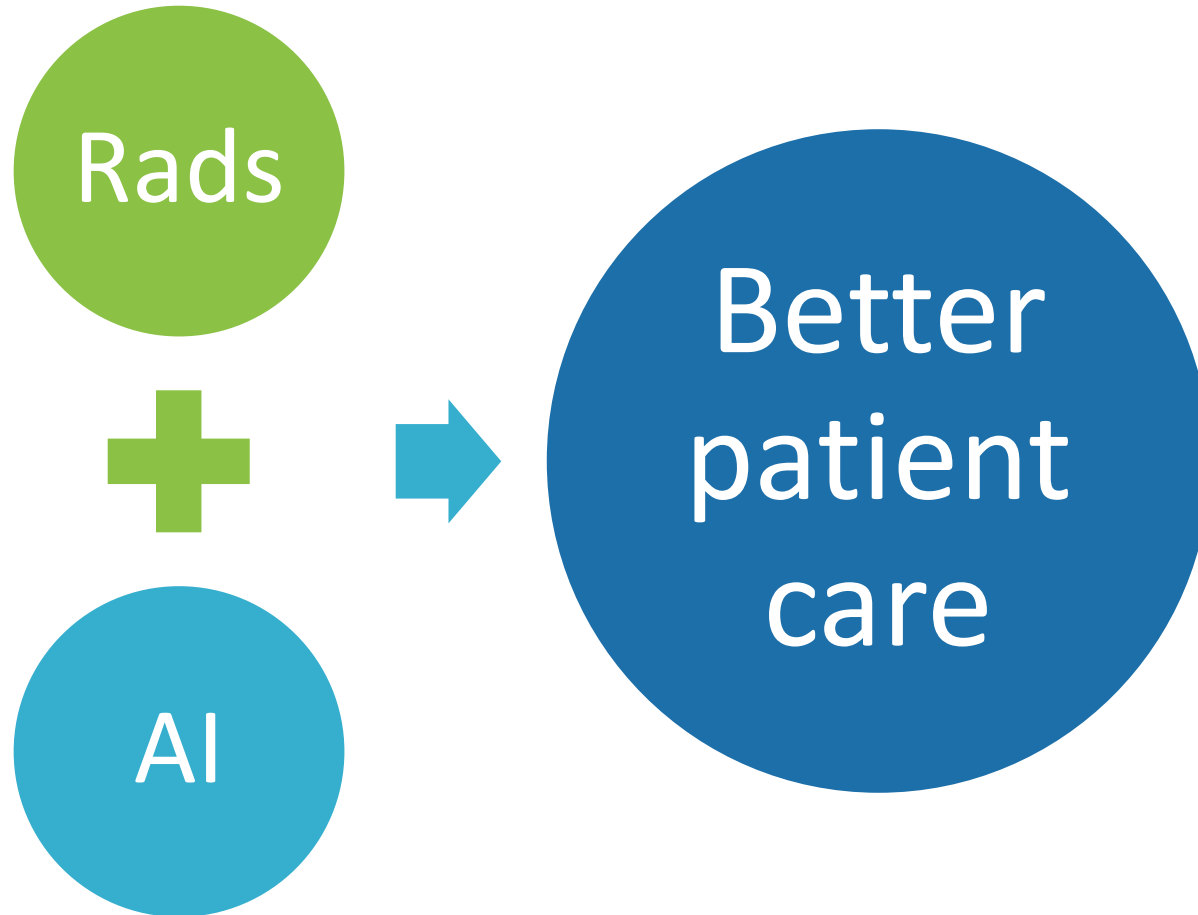
Als: New  
Robot  
Radiologists?

No.

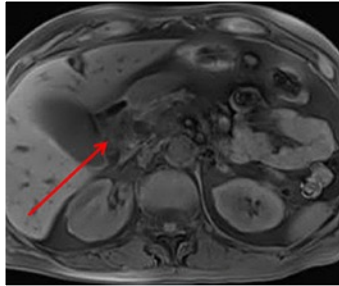




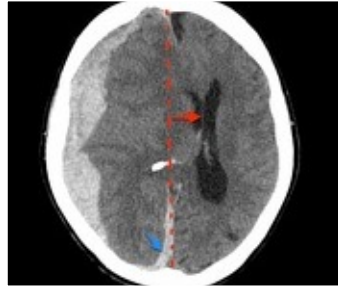
# AI & Radiology: Better Together



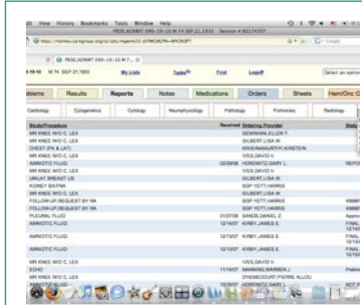
# Use Cases for Imaging AI



Findings detection



Case triage



EMR search



Reporting QI & QC

Patient 1	Patient 2	Patient 3	Patient 4
7:30 am Check-in am scan	CT: 7:50 am Check-in 8:20 am scan	Lab: 7:30 am	Lab: 8 am
8:30 am	H&P: 9 am	CT: 8:10 am Check-in 8:40 am scan	CT: 8:30 am Check-in 8 am scan
9:10 am	Lab: 10 am	H&P: 9 am	H&P: 10 am
Dietician and social worker discussion			
Lunch			
Consultation with specialists			

Schedule optimization

4. Stay focused and engaged - do not distract others. Disruptions will not be tolerated.

5. Remain in your seat during class unless given permission to move.

6. Follow ALL rules in the Student Handbook.

**Technology Policies**

Cell phones are not to be visible in class unless permission is given. Earbuds and headphones are NOT to be worn in this classroom or in the lab.

**Consequences**

1. Warning or conference after class.
2. Visible cell phones will be confiscated; referral may occur if there are repeat offenses.
3. Disruptions will result in removal from class and/or detention after class. Referrals will occur for repeat offenses.
4. Parents may be contacted to discuss a behavior modification plan.

**Passes**

Asking for passes should not cause a disruption in class. Library and tutoring passes should be requested OF THE CLASS or during your classroom time. Bathroom and locker passes should be kept to a minimum (also do not disrupt class) to ask for one unless it is an emergency.

**Grading**

A = 90-100% | B = 80-89% | C = 70-79% | D = 60-69%

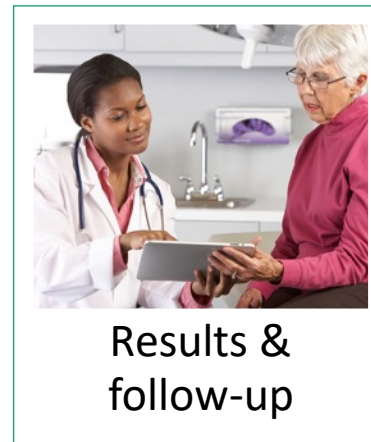
You will accumulate points throughout the semester. Your grade is based on your overall percentage of points. There will be no extra credit. Late work will not be accepted more than 1 week from the due date. Late work will have point deductions.

All homework is due at the BEGINNING of class unless otherwise stated.

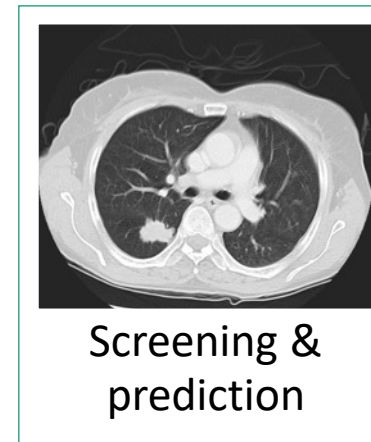
**Cheating:**

Protocols

Billing & RVUs



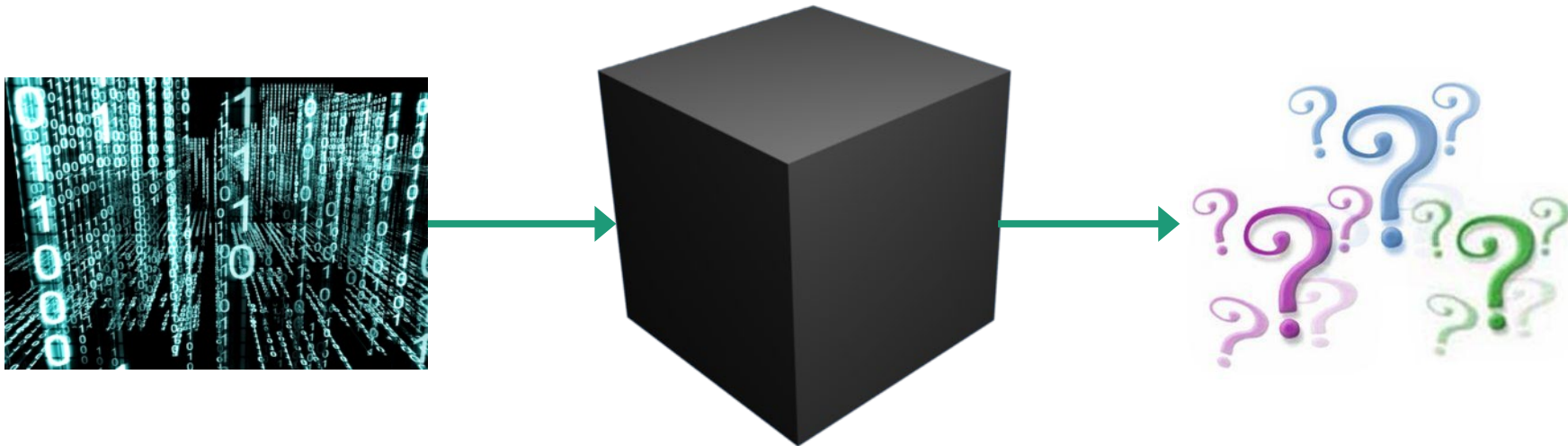
Results & follow-up



Screening & prediction

# AI “Black Box”

- “transparency, interpretability, and explainability are necessary to build patient and provider trust” - *Ethics of AI in Radiology: European and North American Multisociety Statement, 2020*







# The Devil is in the ~~Details~~ Data

- Data selection
- Expert labeling
- Quality vs. quantity
- Bias

Radiology:Artificial Intelligence

[Current Issue](#) | [All Issues](#) | [Magician's Corner](#) | [For Authors](#) | [CLAIM](#) | [Editor's Blog](#)

Posted 7/15/2020

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## Combatting Bias in Medical AI Systems

by Charles E. Kahn, Jr, MD, MS  
Editor, Radiology:Artificial Intelligence

Those of us who see the great potential of artificial intelligence in radiology are eager to assure that AI systems work to the benefit of all of our patients. To do so, we must be aware of possibilities for error. In quality management, a latent error is a failure that is "waiting to happen," often due to an oversight in design or execution.

Modern AI systems are complex: they can entail hundreds of layers with thousands of connections. The complexity and opacity of deep learning models can engender a variety of systematic errors. It's well known that deep learning systems can associate extraneous features with their intended goals. Systems that were intended to recognize pneumothorax may, in fact, have learned to detect the presence of an associated chest tube. Other examples abound.

Adversarial images highlight another challenge to AI. If merely rotating an image or adding a small amount of noise can alter the AI system's output radically - changing the diagnosis of a malignant lesion into one classed as "benign," for example - how can we know when a system works properly?

With these potential errors in mind, we also must consider the often-invisible role of bias.

**BIAS  
in AI**

# Integrating AI into the Radiology Workflow



# Artificial Intelligence May Cause a ~~Significant Disruption to the~~ Radiology Workforce



*Maciej A. Mazurowski, PhD*

## Disruptive Innovation

### Abstract

The increasingly realistic prospect of artificial intelligence (AI) playing an important role in radiology has been welcomed with a mixture of enthusiasm and anxiousness. A consensus has arisen that AI will support radiologists in the interpretation of less challenging cases, which will give the radiologists more time to focus on the challenging tasks as well as interactions with patients and other clinicians. The possibility of AI replacing a large number of radiologists is generally dismissed by the radiology community. The common arguments include the following: (1) AI will never be able to match radiologists' performance; (2) radiologists do more than interpret images; (3) even if AI takes over a large portion of the reading tasks, the radiologists' effort will be shifted toward interactions with patients and other physicians; (4) the FDA would never agree to let machines do the work of radiologist; (5) the issues of legal liability would be insurmountable; and (6) patients would never put complete trust in computer algorithms. In this article, I analyze these arguments in detail. I find a certain level of validity to some of them. However, I conclude that none of the arguments provide sufficient support for the claim that AI will not create a significant disruption in the radiology workforce. Such disruption is a real possibility. Although the radiology specialty has shown an astonishing ability to adapt to the changing technology, the future is uncertain, and an honest, in-depth discussion is needed to guide development of the field.

**Key Words:** Artificial intelligence, future of radiology, machine learning, opinion

*J Am Coll Radiol 2019;16:1077-1082. Copyright © 2019 Published by Elsevier Inc. on behalf of American College of Radiology*



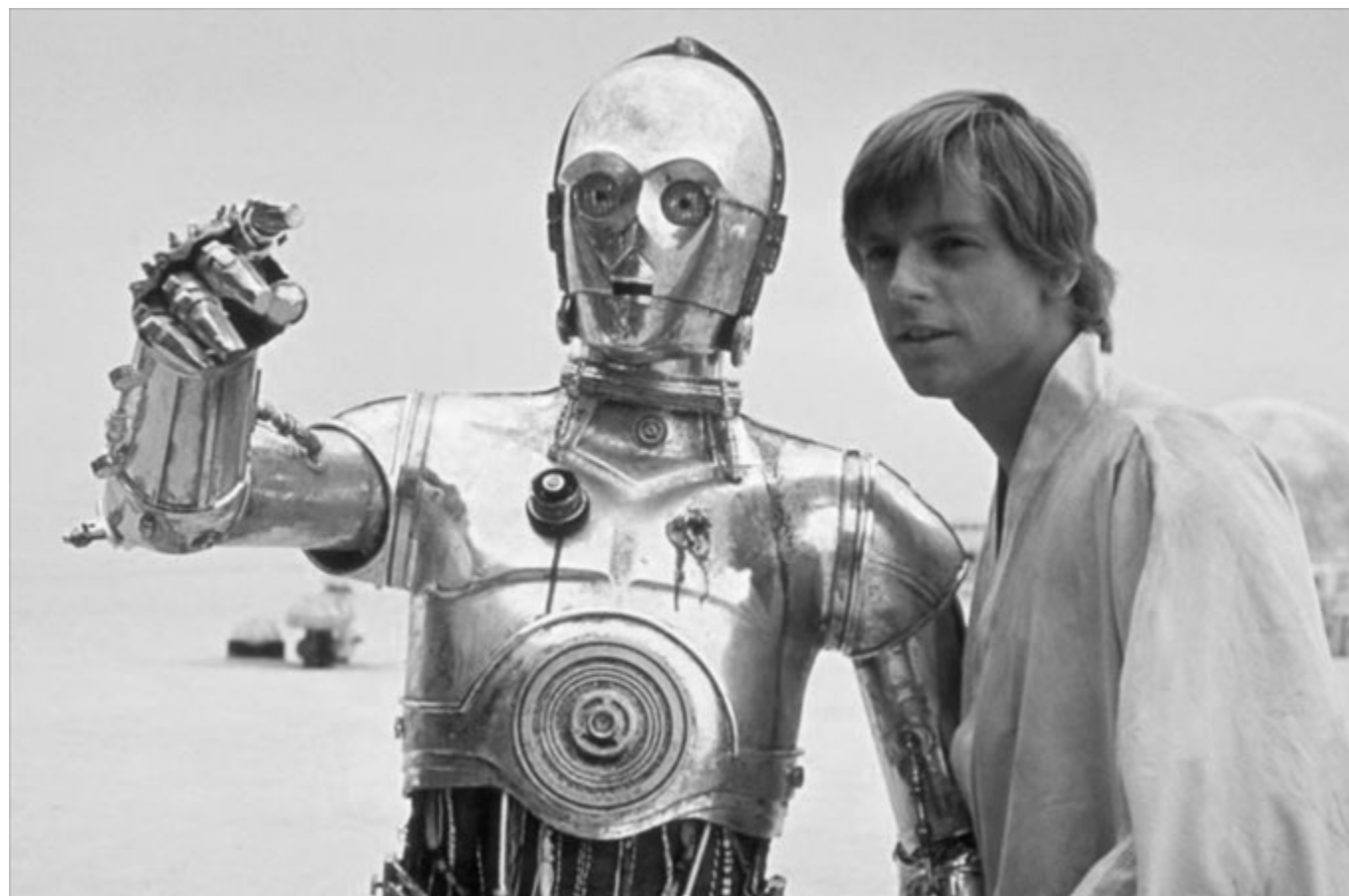


# Radiology AI: Goals

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- Decrease image acquisition time
- Increase measurement accuracy
- Decrease repetitive tasks
- Facilitate reporting
- Augment expert physician reader

# The Future of AI in Radiology



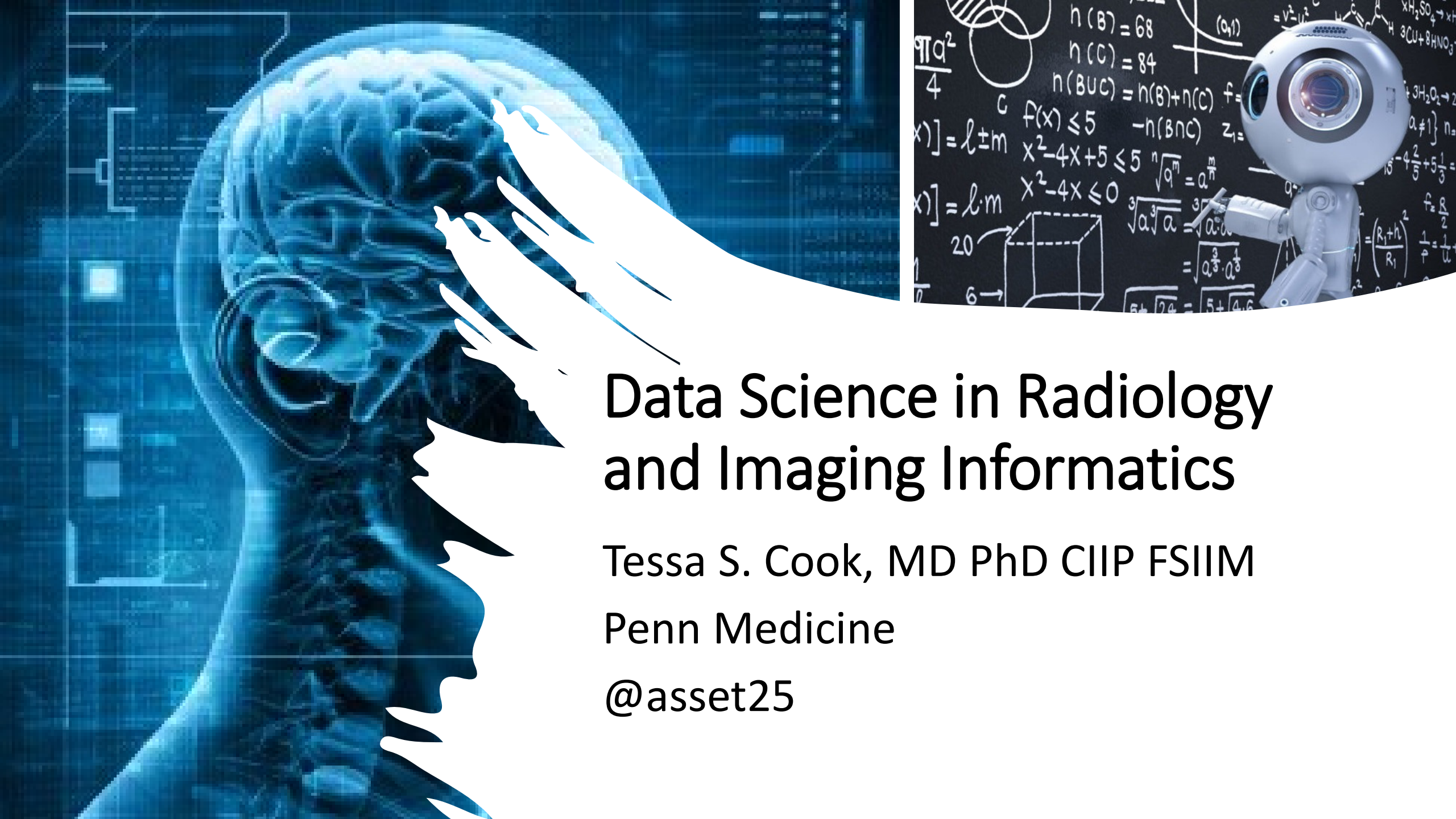


In Conclusion



Questions?





# Data Science in Radiology and Imaging Informatics

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