Why We Need Physicists in Diagnostic Imaging?

Ehsan Samei

Disclosures

- Siemens Healthcare
- GE Healthcare
- Bracco Diagnostics
- Imalogix
- METIS Health Analytics
- 12Sigma
- CIRS
- Gammex

Historical grounding

- Remember Roentgen, Curie, Hounsfield, Cormack, …
- The foundational discipline behind Diagnostic Radiology
- Physics applications to
  – Design technologies with superior performance
  – Ensure intrinsic performance of technology
  – Establish and affirm standards of practice

Overarching need and presuppositions

Medicine: Discerning and intervening in the health state of the patient with sufficient accuracy, precision, and safety for definitive clinical outcome

Healthcare is about the patient, not the particularities of the techniques – techniques are valued to the extent they benefit the patient

Reality check 1:
Clinical practice

Heterogeneous, Compounded, Complex

- Varying technologies
- Varying technical parameters
- The patient factor
  – limited dynamic adaptation of technology to the patient
- The human factor
- Competing interests

Variability in the quality of care

Reality check 2:
Cultural shifts in healthcare

Evidence-based medicine
- Practice informed by science

Precision medicine
- Personalization of care in quantification terms

Comparative effectiveness - meaningful use
- Enhanced focus on actual utility

Value-based medicine
- Scrutiny on safety, performance, consistency, stewardship, efficiency (leanness), ethics

Drive towards innovative, high-quality, consistent, patient-centric, evidential, precise, and safe healthcare

What is the role of medical physicist?

Innovative precision care through clinical application of physical sciences

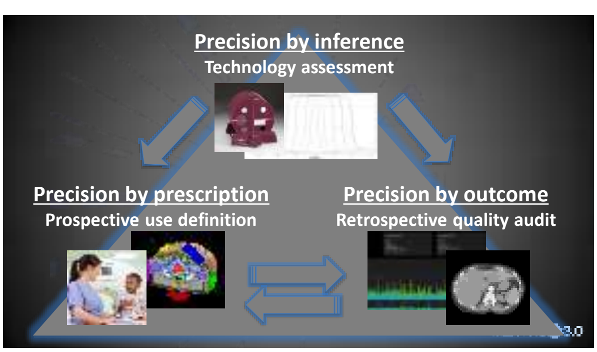
Why Physics in Medicine?

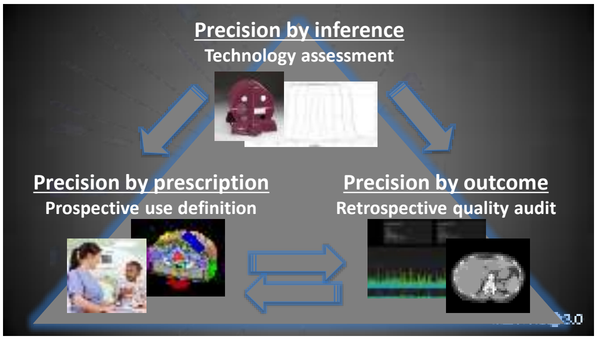
Samei and Grist, Why Physics in Medicine? JACR, 2018

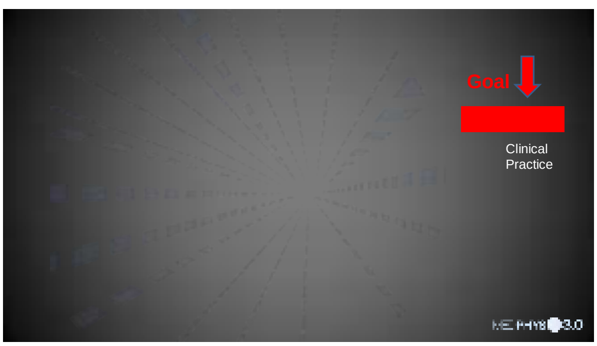
Why Physics in Medicine?

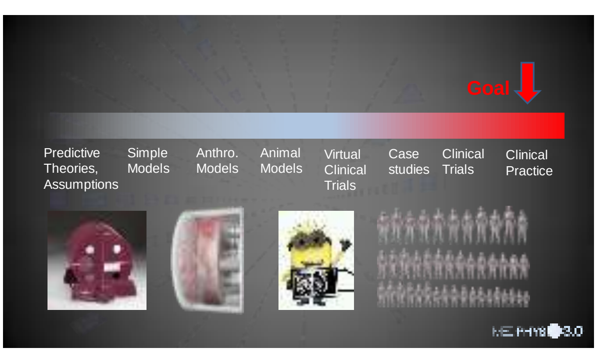
1. Cultural trajectories in medicine call for a close relationship
2. New technologies call for a close relationship
3. Radiological competency calls for medical physics
4. New physics for new technologies and new priorities: Modern medical physics in practice: assessment, optimization, analytics

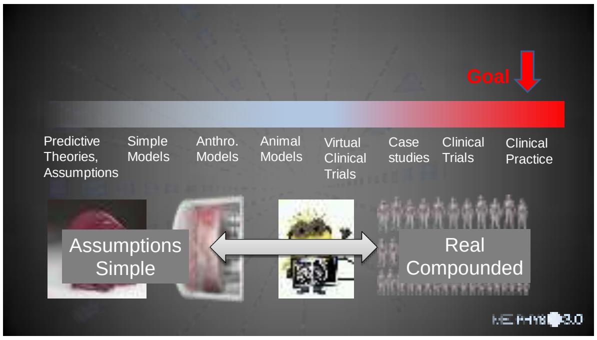
Samei and Grist, Why Physics in Medicine? JACR, 2018



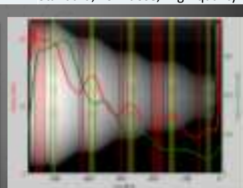

Precision by inference
Technology assessment
Precision by prescription
Prospective use definition
Precision by outcome
Retrospective quality audit


Goal
Clinical Practice

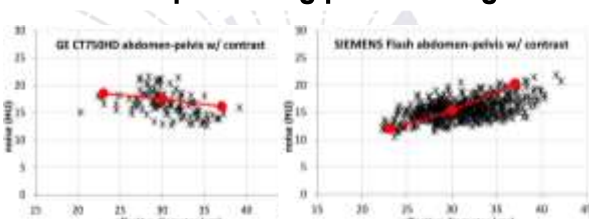

Goal
Predictive Theories, Assumptions
Simple Models
Anthro. Models
Animal Models
Virtual Clinical Trials
Case studies
Clinical Trials
Clinical Practice



Vendor	Algorithm	Parameter
GE	AutomA, SmartmA	Noise Index
Philips	D-DOM, Z-DOM	Reference Image
Siemens	CARE Dose, CARE Dose4D	Quality reference mAs
Toshiba	SURE Exposure, SURE Exposure 4D	Standard, Low-dose, High-quality
Hitachi	Adaptive mA, IntelliEC	Standard, Low-dose, High-quality

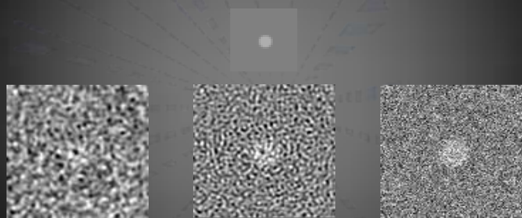


Phantom predicting patient images?

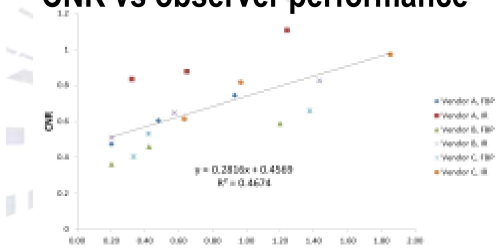


Ria et al, AAPM 2018

Is CNR good enough?



CNR vs observer performance



Christianson, et al, Radiology, 2015

FBP Reconstruction

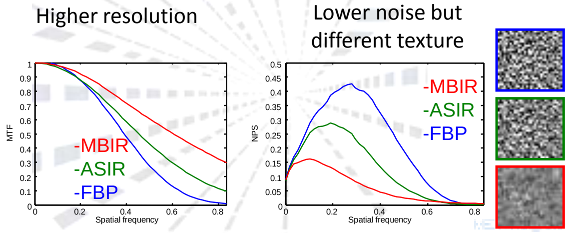
Iterative Reconstruction

Courtesy of Dr de Mey and Dr Nieboer, UZ Brussel, Belgium

Resolution and noise, example

Higher resolution

Lower noise but different texture

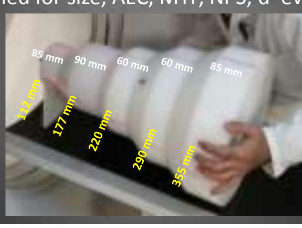


Task-based measurements (AAPM TG233)

Mercury Phantom 3.0

Size matching population cohorts

Designed for size, AEC, MTF, NPS, d' evaluations



Task-based quality index

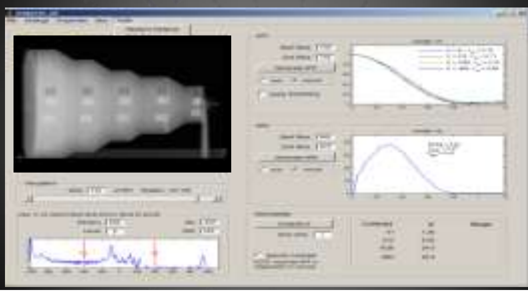
Resolution and contrast transfer × Attributes of image feature of interest

Image noise magnitude and texture

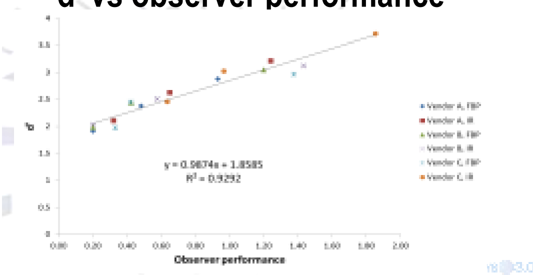
$$\left(d'_{NPWE}\right)^2 = \frac{\left[\iint MTF^2(u,v)W^2_{Task}(u,v)E^2(u,v)dudv\right]^2}{\iint MTF^2(u,v)W^2_{Task}(u,v)NPS(u,v)E^4(u,v) + MTF^2(u,v)W^2_{Task}(u,v)N_i\, dudv}$$

Richard, and E. Samei, Quantitative breast tomosynthesis: from detectability to estimability. Med Phys, 37(12), 6157-65 (2010).
Chen et al., Relevance of MTF and NPS in quantitative CT: towards developing a predictable model of quantitative... SPIE 2012

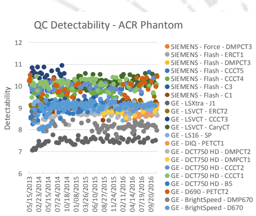
Automated Characterization



d' vs observer performance

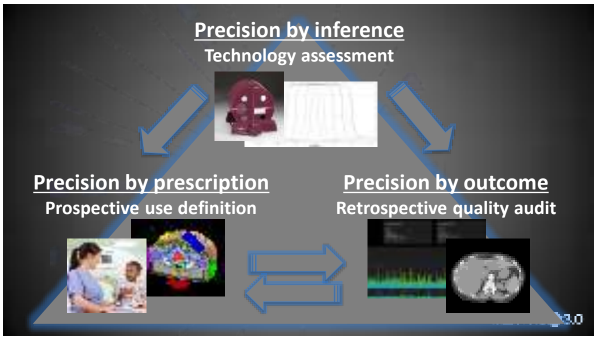


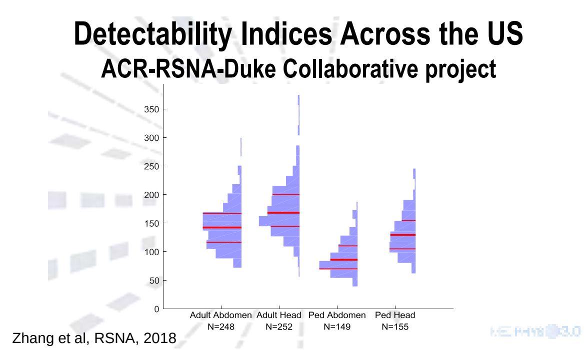
Detectability Indices Across Systems

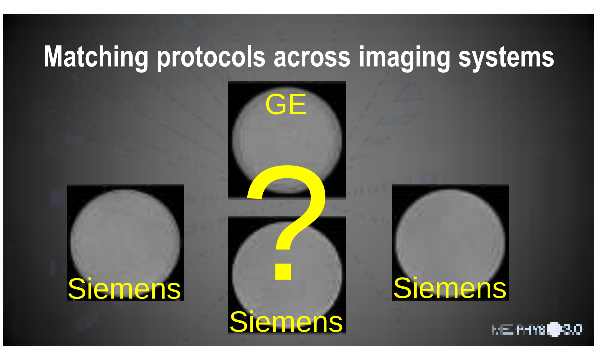


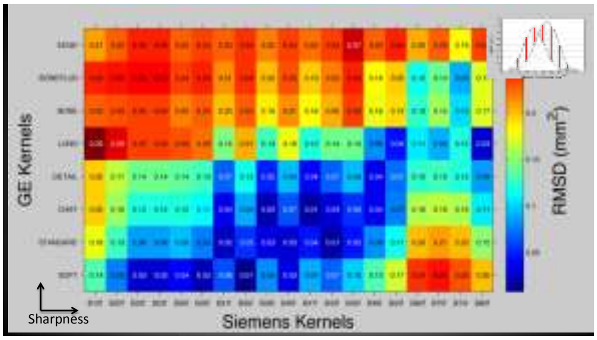
Intersystem Variability	8.0%
Intrasystem Variability	
SIEMENS - Force - DMPCT3	0.1%
SIEMENS - Flash - ERCT1	1.0%
SIEMENS - Flash - DMPCT3	3.5%
SIEMENS - Flash - CCCT5	1.9%
SIEMENS - Flash - CCCT4	4.2%
SIEMENS - Flash - C3	2.1%
SIEMENS - Flash - C1	2.4%
GE - LSXtra - J1	2.4%
GE - LSVCT - ERCT2	3.1%
GE - LSVCT - CCCT3	2.0%
GE - LSVCT - CaryCT	1.7%
GE - LS16 - SP	2.1%
GE - DIQ - PETCT1	3.2%
GE - DCT750 HD - DMPCT2	2.8%
GE - DCT750 HD - DMPCT1	1.4%
GE - DCT750 HD - CCCT2	1.8%
GE - DCT750 HD - CCCT1	2.2%
GE - DCT750 HD - B5	3.0%
GE - D690 - PETCT2	3.0%
GE - BrightSpeed - DMP670	2.4%
GE - BrightSpeed - D670	3.8%

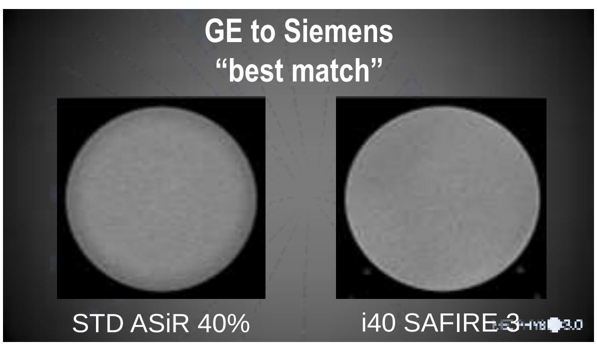
Intra-system variability: 1-4% Inter-system variability: 8%

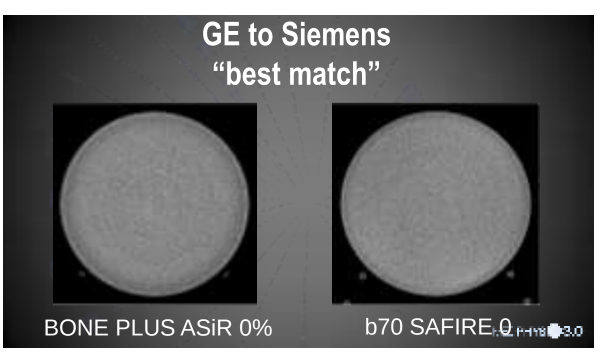

Precision by inference
Technology assessment
Precision by prescription
Prospective use definition
Precision by outcome
Retrospective quality audit

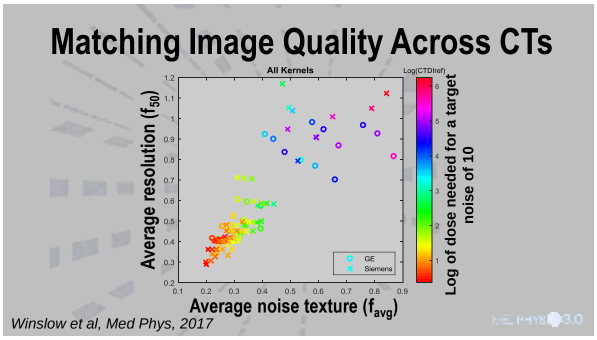

Detectability Indices Across the US
ACR-RSNA-Duke Collaborative project
350
300
250
200
150
100
50
0
Adult Abdomen N=248
Adult Head N=252
Ped Abdomen N=149
Ped Head N=155
Zhang et al, RSNA, 2018


Matching protocols across imaging systems
GE
?
Siemens
Siemens
Siemens

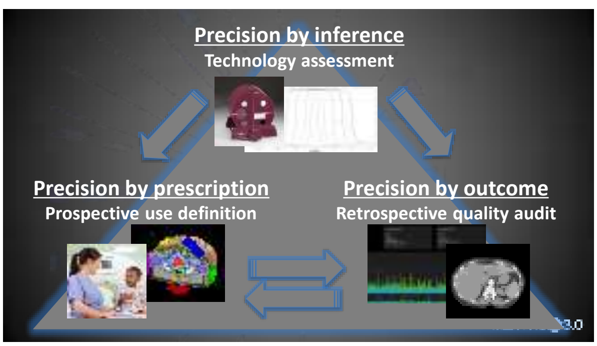

GE Kernels
Siemens Kernels
RMSD (mm²)
Sharpness


GE to Siemens
"best match"
STD ASiR 40%
i40 SAFIRE 3

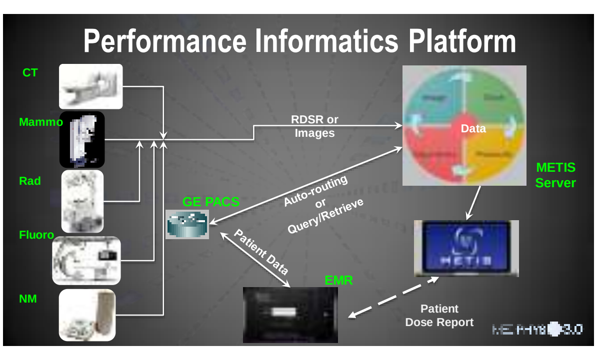

GE to Siemens
"best match"
BONE PLUS ASiR 0%
b70 SAFIRE 0



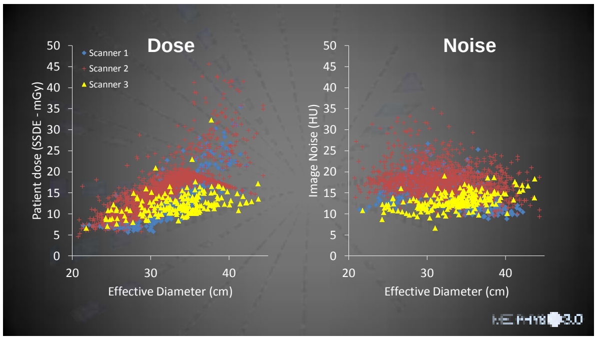
Matching Image Quality Across CTs
All Kernels
Average resolution (f50)
Average noise texture (favg)
Log of dose needed for a target noise of 10
GE
Siemens
Winslow et al, Med Phys, 2017



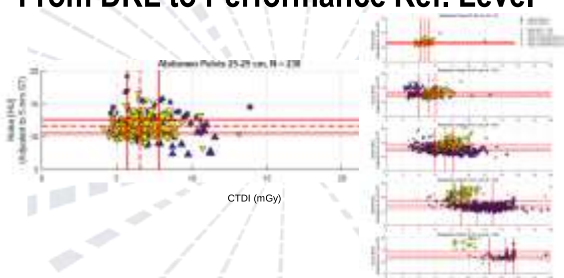
Precision by inference
Technology assessment
Precision by prescription
Prospective use definition
Precision by outcome
Retrospective quality audit



Performance Informatics Platform
CT
Mammo
Rad
Fluoro
NM
RDSR or Images
GE PACS
Auto-routing or Query/Retrieve
Patient Data
EMR
Data
METIS Server
Patient Dose Report



From DRL to Performance Ref. Level



Take-home Points

41

Take-home Points

- Competent, effective medical physics is about
  - Quality patient care
  - Quality Assurance in the full sense of the word:
    - Predictive characterization
    - Targeted optimization
    - Clinical performance monitoring
    - Corrective actions

How we get there?

MP3.0:

Claiming our roles as scientists, care providers, and leaders aimed towards patient centric, value-based promotion of health

MP3.0 “Smarts” initiative

1. Smart regulations (accreditation, etc)
2. Smart tools
3. Smart practitioners
4. Smart practice
5. Smart advocacy
6. Smart grassrooting
7. Smart expansion