Why We Need Physicists in Diagnostic Imaging?

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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 (leaness), 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?

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

Precision by inference
Technology assessment

Precision by prescription
Prospective use definition

Precision by outcome
Retrospective quality audit
**Goal**

- Predictive Theories Assumptions
- Simple Models
- Anthrop. Models
- Animal Models
- Virtual Clinical Trials
- Case studies
- Clinical Trials
- Clinical Practice

**Assumptions**
- Simple

**Real Compounded**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Algorithm</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>AutomA, SmartmA</td>
<td>Noise Index</td>
</tr>
<tr>
<td>Philips</td>
<td>D-DOM, Z-DOM</td>
<td>Reference Image</td>
</tr>
<tr>
<td>Siemens</td>
<td>CARE Dose, CARE Dose4D</td>
<td>Quality reference mAs</td>
</tr>
<tr>
<td>Toshiba</td>
<td>SURE Exposure, SURE Exposure 4D</td>
<td>Standard, Low-dose, High-quality</td>
</tr>
<tr>
<td>Hitachi</td>
<td>Adaptive mA, IntelliEC</td>
<td>Standard, Low-dose, High-quality</td>
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</tbody>
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**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

\[
(d_{\text{req}})^2 = \frac{\int \int \text{MTF}^2(u,v)W_{\text{Task}}^2(u,v)E^2(u,v) \, du \, dv}{\int \int \text{MTF}^2(u,v)W_{\text{Task}}^2(u,v)NPS(u,v)E^2(u,v) + \text{MTF}^2(u,v)W_{\text{Task}}^2(u,v)N_d(u,v) \, du \, dv}
\]
Automated Characterization

**D' vs observer performance**

\[ y = 0.8674x + 1.8585 \]
\[ R^2 = 0.9292 \]

**Detectability Indices Across Systems**

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

[Graph showing detectability indices across systems]
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Detectability Indices Across the US
ACR-RSNA-Duke Collaborative project

Zhang et al., RSNA, 2018

Matching protocols across imaging systems

GE
Siemens
Siemens
Siemens
GE to Siemens
“best match”

STD ASiR 40%  i40 SAFIRE 3

BONE PLUS ASiR 0%  b70 SAFIRE 0
From DRL to Performance Ref. Level

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

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

How we get there?
MP3.0:
Claiming our roles as scientists, care providers, and leaders aimed towards patient centric, value-based promotion of health