MEDICAL PHYSICS 2.0:
RADIOGRAPHY 2.0

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Disclosure

• Nothing to disclose

Learning Objectives

• Identify the likely changes in medical physics services for radiographic systems over the next 5-10 years
• Understand how to utilize data to identify quality issues and recommend changes that can improve performance in digital radiography
• Understand how to employ modern image performance metrics to analyze image quality and assist facilities in optimizing the capabilities of radiographic systems
• Recognize the value of data logging capabilities of modern digital radiographic systems
• Utilize modern process control methods to monitor stability
Medical Physics 2.0: Radiography

• Philosophy and Significance
• Physics Metrics and Analytics
  - Dosimetry
  - Image Quality
• Testing implication of new technologies
• Clinical integration and implementation
  - Training and communication
  - Optimization
  - Automated analysis and data management
  - Meaningful QC

Philosophy

Philosophy: Personalized Medicine

• Better knowledge of your “patient”
• Can “Personalized medicine” be applied to medical physics?
  - Focused testing can be more insightful, more cost-effective
  - Focus on the most important and prevalent potential problems
  - Think: Medical Physics “appropriateness criteria”
"Choosing Wisely" in Medical Physics?

- "... to ensure that the right care is delivered at the right time"
- "... evidence-based recommendations ... to help make wise decisions about the most appropriate care based on a patient's individual situation"
- ➔ be more selective about what tests are performed

Philosophy: Health Care Economics

- "Value-based reimbursement" vs. "Fee for service"
  - Policy-makers and payers want "value-based purchasing"
    - Compensation based on work quality and outcomes, not volume
  - Radiology payment is moving away from fee-for-service model and toward data-driven value-based payment based on service quality
- Will medical physics move in the same direction?
- How to measure "value"?
  - Value = Quality / Cost
  - Can we measure the quality of a radiologist's report?
  - Can we measure the quality of a medical physicist's work?
Medical Physics 1.0: Radiography

• Focused on detailed equipment evaluation
• Tests are driven in large part by regulation
  – And sometimes superstition?
• Testing and strategy has persisted largely unchanged even though radiography equipment has changed drastically
• The bigger picture of the process is often ignored
Areas of focus

- Generator
- Timer
- X-ray tube
- Collimator
- AEC system
- Bucky and image receptor
- Workstation monitors

Medical Physics 2.0: Radiography

- Regulatory compliance must still be achieved
- Medical physics can & should add value
  - Modern quality control methods
  - Data analytics
  - Detecting unstable or aberrational system behavior
  - Recommending preemptive or corrective action
  - Comparative Effectiveness Research to guide capital equipment decisions
  - "Post-market research"

Physics metrics and analytics

- Traditional measurements ("radiometrics") will continue to be important to verify the output of x-ray systems.
  - kVp accuracy
  - Radiation output (mR/mAs at a fixed distance)
  - HVL
  - Exposure reproducibility
  - mAs/mAs linearity
  - X-ray tube focal spot size
Physics metrics and analytics
• Modern tools for radiometrics makes this easier than ever before

Physics metrics and analytics
• Other physics metrics from MP 1.0 that will not go away:
  • AEC performance
  • Reproducibility
  • kVp tracking
  • Thickness tracking
  • Cell balance
  • Calibration of AEC system to the image receptor
    • Verification that AEC achieves desired exposure indicator
    • Determine image receptor dose

Physics metrics and analytics
• Image receptor evaluation
  • Exposure Indicator calibration
    • See AAPM Report #116
  • Target Exposure Indicator (EIₜ) appropriateness
• Image receptor imaging performance
  • Vendor-provided QA testing
  • “Vendor-neutral” test procedures (AAPM TG 150 + others)
  • Advanced quantitative methods
    • MTF
    • NPS
Physics metrics and analytics

- Much vendor-provided QA is automated analysis of simple flat-field images
  - Signal non-uniformity
  - Noise (SNR) non-uniformity
  - Correlated noise
  - Dark (electronic noise)

- Vendor-neutral testing of image receptor performance using flat-field images
  - Signal non-uniformity
  - Noise (SNR) non-uniformity
  - Noise texture (NPS)
  - Correlated noise (NPS)
  - Dark (electronic noise)

- It may be difficult to obtain unprocessed images for analysis
- Analysis software is being developed
Physics metrics and analytics

- Attention to grid quality
  - With an understanding of the non-uniformity characteristics of the detector, it will be possible to quantitatively evaluate the non-uniformity of grids
  - SNR Improvement Factor evaluation
    - Fetterly and Schueler, 2009
    - Mizuta, 2012
  - Measurement of grid ratio
    - Pasciak and Jones, 2009

Courtesy David Gauntt, Ph.D.

Medical Imaging Group at Alma Mater Studiorum – University of Bologna, Italy
Physics metrics and analytics

- Image post-processing
  - A major contributor to image quality and diagnostic performance
  - Highly variable between vendors
  - Poorly documented, difficult to understand and troubleshoot
  - Carries potential for failure that can resemble hardware problems or technique errors.
- Should medical physics 2.0 include characterization of image processing failures?

Image processing segmentation error:
Deviation Index (DI) = -18.2

Proper image segmentation:
Deviation Index (DI) = -0.4
Physics metrics and analytics

• Image post-processing
  - Difficult/impossible to test image post-processing performance in the QA sense
  - Stability of image processing can be evaluated
    - Store a set of "FOR PROCESSING" clinical images
    - Store the same set after processing ("FOR PRESENTATION") using standard algorithm and parameters
    - Reprocess the "FOR PROCESSING" set periodically
    - Subtract newly processed images from original set, and check for non-zero pixels (i.e., changes)

Testing Implications of the New Technology

Variety of commercial digital radiography systems available
+ lack of standards for evaluation
= Variable quality assessment

• Standardized (vendor-neutral) test protocols encouraged
• Best practices should be become available over time

Testing Implications of the New Technology

• The “new technology” in radiography
  - Flat-panel DR (wired/wireless) including mobile
  - Tomosynthesis
  - Dual-energy
  - CMOS sensors
  - Photon counting detectors
  - 3D imaging (but don’t call it “CT”)
    - Dental / maxillofacial
    - ENT (head & neck)
  - Vascular imaging (C-arm “rotational angiography”)
  - Orthopaedics / Surgery
  - Etc.
  - Hybrid imaging
Clinical implementation

- Close cooperation among
  - Physicist
  - Radiologist
  - Chief Technologist
- Training and communication
  - Definitions of EI, EI_T, DI
  - Identification of artifacts
  - Identification of image processing errors/failures
  - Protocol ("technique chart") review, including EI, appropriateness
- Statistical analysis of EI/DI
- New methods for 3D dose & image quality evaluation

Clinical implementation

CR/DR Exposure Indicator Analysis

Pooled data

Grouped by location

Outpatient  ED  Portables

Neuro  Neuro OR

Grouped by location

Jaydev Dave, PhD
Clinical implementation

CR/DR Exposure Indicator Analysis

Grouped by Day of the Week

Jaydev Dave, PhD

Clinical implementation

CR/DR Exposure Indicator Analysis

Grouped by Month

Jaydev Dave, PhD

Clinical implementation

CR/DR Exposure Indicator Analysis

Trend analysis

Jaydev Dave, PhD
Clinical implementation

- For DI to be meaningful, target EI (EI_T) must be set carefully
  - Should be appropriate for the exam and view
- EI_T must be consistent throughout enterprise
  - Some systems include default EI-values
  - Some systems calculate EI_T using average of first N images of each Exam/View
  - Can lead to inconsistent EI_T and meaningless DI
- "EI_T Management" – an important new job for the QMP

Medical Physics 2.0 and beyond

- Big data, data mining, data analytics
  - How can we use these emerging technologies to help us be more effective?
  - Imagine a massive online database of shared medical physics QA data
  - Baby step: DXIMGMEDPHYS listserv crowdsourcing
  - Bigger steps: ACR Dose Index Registry, QIBA "Imaging Data Warehouse"
  - Future: Central repository of QA data?
- Advanced statistical analysis
  - Employ statistical process control methods to identify deviations, outliers
    - Shewhart control charts, CUSUM (cumulative sum) charts

Medical Physics 2.0: Radiography

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<tr>
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<th>1.0</th>
<th>2.0</th>
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<tbody>
<tr>
<td>Focus of MP’s attention</td>
<td>Equipment</td>
<td>Patient</td>
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<tr>
<td>MP’s mission</td>
<td>Measure, report on-quality; Adequate on solutions; Technology focus</td>
<td>Measure to generate operational improvements; enhance pt experience; optimize &amp; control imaging process</td>
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<td>MP work environment</td>
<td>Semi-isolated</td>
<td>Integrated into clinical operations</td>
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<tr>
<td>Image quality evaluation</td>
<td>Visual, subjective</td>
<td>Mathematical, quantitative</td>
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<td>Imaging Technologies</td>
<td>S/F, CR, DR</td>
<td>CMOS, Tomosynthesis, 3D, Hybrid, Dual Energy</td>
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<td>Anti-scatter grid</td>
<td>Often ignored</td>
<td>Quantitative evaluation</td>
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<td>Imaging performance tools of the trade</td>
<td>Dots/holes, line pairs, wire mesh</td>
<td>MTF, NPS, DQE, SNR uniformity, noise source analysis</td>
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<td>Radiography QC</td>
<td>Spot-check EI values, quality problems</td>
<td>Continuous automated monitoring of EI (DAP?), focus on trends &amp; outliers</td>
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<tr>
<td>Dosimetry</td>
<td>ESE, ESSAK DAP Standard phantoms</td>
<td>Personalized organ dose (?)</td>
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<tr>
<td>Risk estimation</td>
<td>Comparison with natural background, risky behaviors</td>
<td>Risk index (?)</td>
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