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

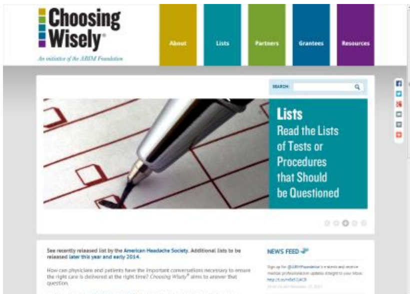
- Philosophy and Significance
- Physics Metrics and Analytics
  - Dosimetry
  - Image Quality
- Testing implication of new technologies
- Clinical integration and implementation
  - Training and communication
  - Optimization
  - Automated analysis and data management
  - Meaningful QC

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?



Choosing Wisely®

An initiative of the ABIM Foundation

- "… 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 patients' 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?

ACR American College of Radiology Quality is Our Image
IMAGING3.0™

A framework to move from volume to value

Medical Physics 1.0

Radiography

A. Kyle Jones, Ph.D.
MD Anderson Cancer Center

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
  - mA/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

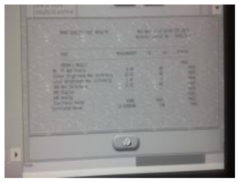
- Other physics metrics from MP 1.0 that will not go away:
  - AEC performance
    - Reproducibility
    - kVp tracking
    - Thickness tracking
    - Cell balance
  - Calibration of AEC system to the image receptor
    - Verification that AEC achieves desired exposure indicator
    - Determine image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

Physics metrics and analytics

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

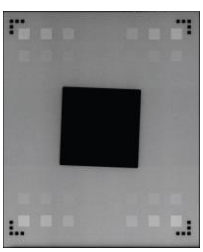
Physics metrics and analytics

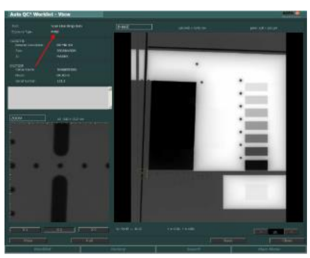
- Much vendor-provided QA is automated analysis of simple flat-field images
  - Signal non-uniformity
  - Noise (SNR) non-uniformity
  - Correlated noise
  - Dark (electronic noise)



Physics metrics and analytics

- Vendor-specific QA phantom testing

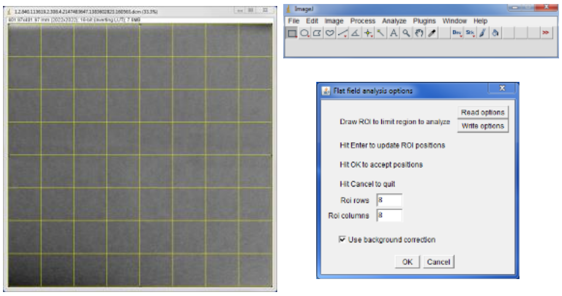




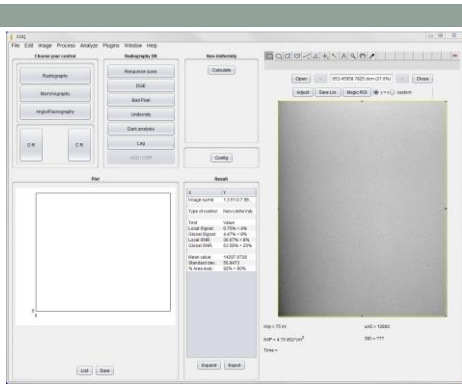
Physics metrics and analytics

- 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



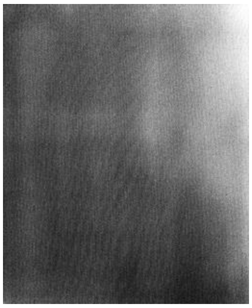
Courtesy David Gauntt, Ph.D.



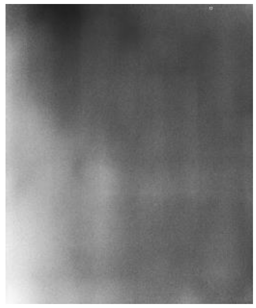
Medical Imaging Group at Alma Mater Studiorum – University of Bologna, Italy

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



Grid line suppression OFF



Grid line suppression ON

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

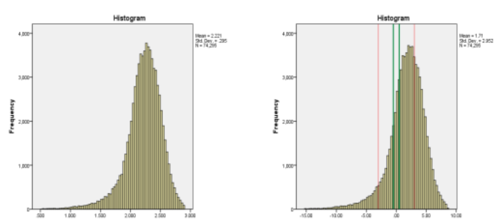
- The “new technology” in radiography
  - Flat-panel DR (wired/wireless) including mobile
  - Tomosynthesis
  - Dual-energy
  - CMOS sensors
  - Photon counting detectors
  - 3D imaging (but don’t call it “CT”)
    - Dental / maxillofacial
    - ENT (head & neck)
    - Vascular imaging (c-arm “rotational 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_T appropriateness
- Statistical analysis of EI/DI
- New methods for 3D dose & image quality evaluation

Clinical implementation

CR/DR Exposure Indicator Analysis

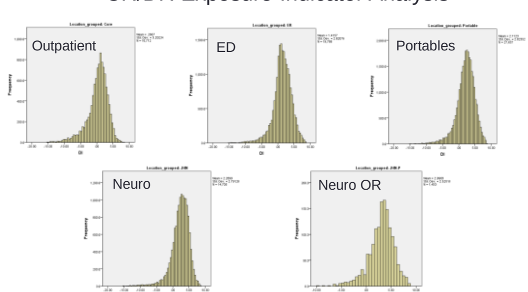


Pooled data

Jaydev Dave, PhD

Clinical implementation

CR/DR Exposure Indicator Analysis

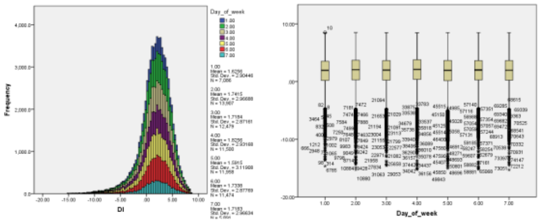


Grouped by location

Jaydev Dave, PhD

Clinical implementation

CR/DR Exposure Indicator Analysis

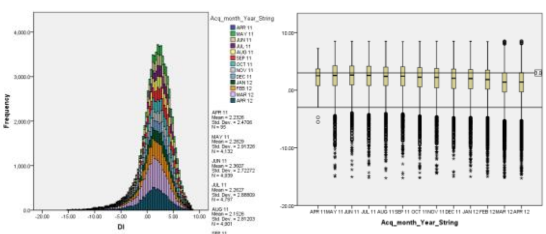


Grouped by Day of the Week

Jaydev Dave, PhD

Clinical implementation

CR/DR Exposure Indicator Analysis



Grouped by Month

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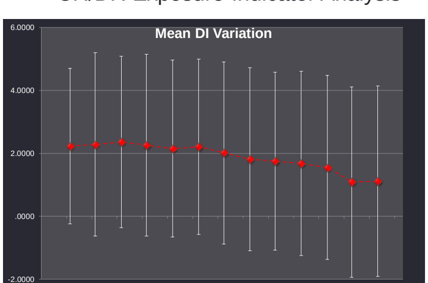
Clinical implementation

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_T 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

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