THE ROLE OF MEDICAL PHYSICS IN ARTIFICIAL INTELLIGENCE IN MEDICAL IMAGING

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Experts in physics and technical principles of medical imaging

- create, evaluate, and deploy of medical imaging technologies
- assess underlying characteristics of image data
- understand how acquisition, reconstruction, and post-processing impact image characteristics
AAPM REPORTS

• **PET/CT Acceptance Testing and Quality Assurance (2019)**
  – A rigorous and ongoing quality assurance program for PET/CT systems

• **Advanced Performance Evaluation of CT Systems (2019)**
  – ... assess image quality using task-specific metrics relevant to predicting performance ... for clinical imaging tasks.

• **Interoperability Assessment for Medical Imaging Systems (2019)**
  – ... data transfer between imaging devices and multiple information systems can lead to communication errors that could affect image quality or diagnostic performance

• **Planar Image Quality Metrology (2017)**
  – characterization of NPS, MTF, DQE, and effective DQE

AAPM reports are rigorously-reviewed, globally-adopted, *de facto* technical standards for assessing image and reader performance and developing quality assurance processes
Considerable impact of system characteristics, acquisition, reconstruction and post-processing parameters

- Kuo et al, *PNAS 2019*: **AUC of 99%** for stroke detection
  - 4,396 cases with **strong labels** from pixel-level supervision
  - **minimally varying** image characteristics
    (1 hospital network, 4 scanners, all 64-slice systems)

- Chilamkurthy et al, *Lancet 2018*: **AUC of 95%** for stroke detection
  - 313,318 cases with **weak labels** mined from the EMR
  - **widely varying** image characteristics
    (26 centers, 16 scanner models, 2 to 128 slice systems)

**Data quality matters**
QD = ¼ dose, FD = full dose, CNN = denoising method

Must demonstrate **GENERALIZABILITY** or must characterize and **constrain** input data

Courtesy Nathan Huber
Some parameters are **patient-specific** and cannot be standardized. **Generalizability** can be impacted by patient-specific parameters.
STANDARDIZE INPUT DATA

- Develop standardized exam protocols
- Objectively quantify image characteristics
- Define acceptable range of data characteristics
- Develop tools to translate non-standard data into data with relatively standard characteristics

Physics knowledge needed to ensure high quality data
Create and use synthetic patient data with known truth
- Data created with accurate physics modelling
- Ideal data augmentation method
- Provides standardized data for performance and stress testing
- Avoids variability in
  - Quality of site-specific data collection and labeling
  - Patient cohorts: disease characteristics and prevalence
  - Radiologist interpretations: different training and diagnostic thresholds
- Allows quantitative assessment of algorithms that learn over time

Physics knowledge can yield ideal testing data
LESION INSERTION IN PROJECTION SPACE Captures Impact of Reconstruction Parameters

Original – FBP, 2 mm

w/ Lesion – FBP, 2 mm

w/ Lesion – FBP, 5 mm

w/ Lesion – IR, 2 mm

Summary

MEDICAL PHYSICISTS IN AI IN MEDICAL IMAGING

- Ensure data quality and consistency (e.g., via data translation)
- Create ideal data sets using **accurate physics modelling**
  - Systematic perturbations to assess reproducibility of results
  - Data augmentation for training and testing
- Objectively evaluate commercial products
  - Do they give the right answers?
  - Acceptance testing processes, including defining “tolerances” (e.g., AUC)
  - Quality assurance programs, including defining “tolerances” (e.g., $\Delta$ AUC)