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# Disclosures

- Research support
  - NIH (EB017095, EB028590, EB028591)
  - Mayo Clinic Discovery Translation Grant
  - Siemens Healthcare
- Board membership
  - ISCT, Vice-president
- Use of off-label medical devices
  - The research photon-counting-detector CT scanners described in this work are not commercially available



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# X-ray detectors and medical CT

Typical Parameters for High End Medical CT Systems	
X-ray Spectra	70 kV to 150 kV
X-ray On Time	~0.2 s up to 100 s
Typical Flux	~ 10 <sup>8</sup> photons / (s·mm²)
Peak Flux	> 10 <sup>9</sup> photons / (s·mm²)
Detector Type	Indirect conversion (scintillating EIDs)
Active Area	up to 32 cm x 100 cm
Pixel Pitch	~1 mm x 1 mm
Frame Rate	Up to 7x10 <sup>3</sup> fps
Dynamic Range	18 bit to 22 bit
Signal Stability	~0.1%
Centrifugal Force	Up to 70 g





# Challenges for PCDs in medical CT

- Pulse pile-up
  - Reduces dose efficiency and signal accuracy: pixels can't be too large
- ▶ ① k-escape, charge sharing, and Swank noise
  - Reduces spectral resolution: pixels can't be too small
- Advanced ASIC designs
  - Fast pulse shaping < 10-20 ns FWHM
  - Two or more counters per pixel
- Bandwidth
  - Pixel pitch  $\sim$  0.275 mm x 0.322 mm with 2 counters per pixel
  - > 22 times more data to move
- Large scale manufacturing
  - High purity, high yield, long term stability, affordable cost













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# Clinical benefit

- Increased conspicuity of subtle iodine-enhancing structures or pathology
- Increased iodine CNR could be traded for dose reduction
  - Radiation dose
    - Beneficial for children and patients with chronic disease
  - Iodinated contrast material dose
    - Beneficial for patients with decreased kidney function
- Increased iodine CNR at high kV
  - Obese patients
  - Patients with metal implants









# Temporal bone: Improved resolution and lower noise/dose







# Simultaneous High Resolution & Multi-Energy

- Higher spatial resolution better delineates coronary artery and stent
- Multi-energy enables material decomposition, e.g., iodine map



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# Clinical benefit

125-micron resolution for fine anatomic features

# PLUS

- data perfectly registered temporally and spatially
- ability to diagnose gout or bone marrow edema, perform bone removal, or any other spectral application



# Use of multiple k-edge contrast agents

- Multi-contrast imaging
  - Simultaneous imaging of multiple contrast agents
    - *I,* Gd, Bi
  - <u>Might</u> enable novel molecular imaging applications
    - Au nanoparticles
- Challenges
  - Noise amplification
  - Lack of FDA-cleared high Z contrast agents





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# First cardiac PCD-CT study (April 30, 2021)



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# Clinical impact of photon counting detector CT

- Photon counting detectors (PCDs) record individual photons and their associated energy
- Offers multiple benefits over conventional CT with energy integrating detectors (EIDs)



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