MAYO CLINIC

Mayo Clinic Urolithiasis O'Brien Grant
Project 1: Non-invasive characterization of kidney stones

Cynthia McCollough, PhD (PI)
Shuai Leng, PhD
Terri J. Vrtiska, MD
James Williams, Ph.D.

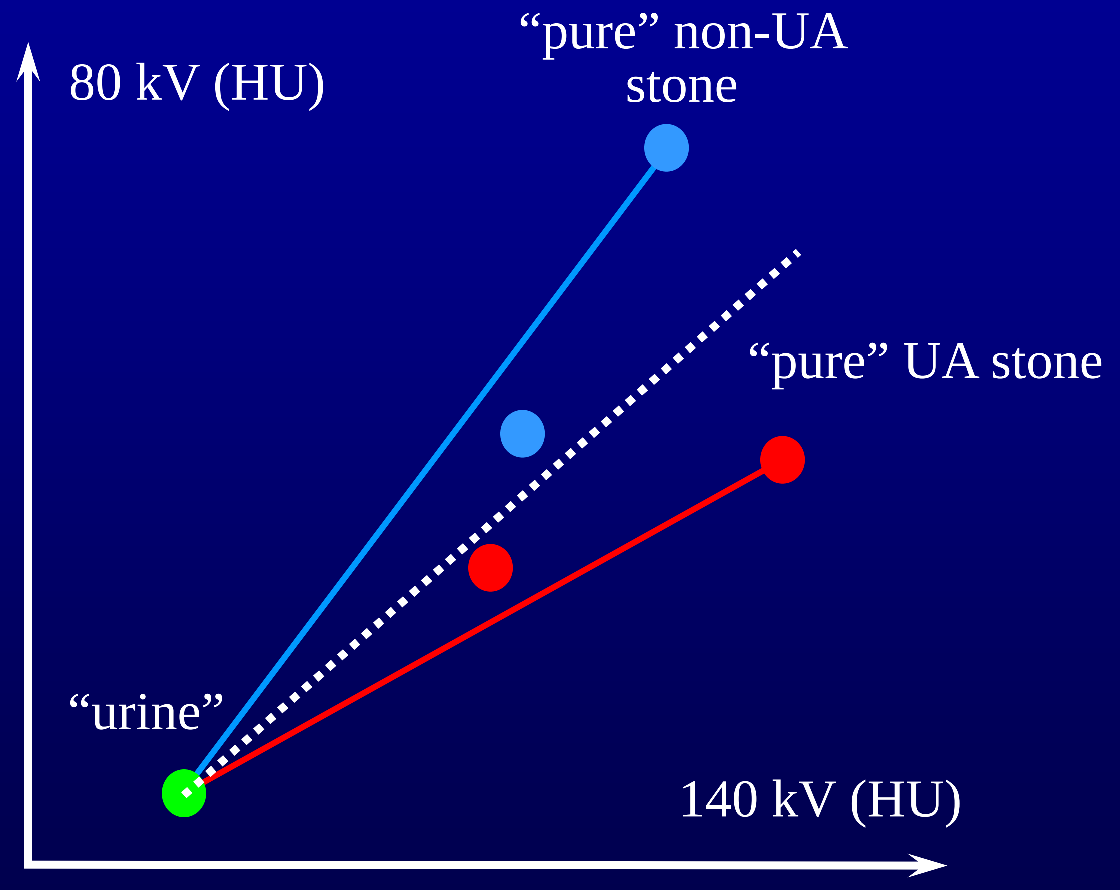
Background

What is dual-energy CT

Dual-energy CT

- Uses two different spectra of x-ray energies to acquire images at a low (e.g. 80 kV) and high (e.g. 140 kV) tube voltage
- The radiation dose to the patient is the SAME as single energy CT
- The two data sets can be used to identify materials having different average atomic numbers, such as differentiating soft tissue from calcium from iodine, because materials with unique atomic numbers (e.g. uric acid and calcium) reside in different regions of a dual-energy data plot

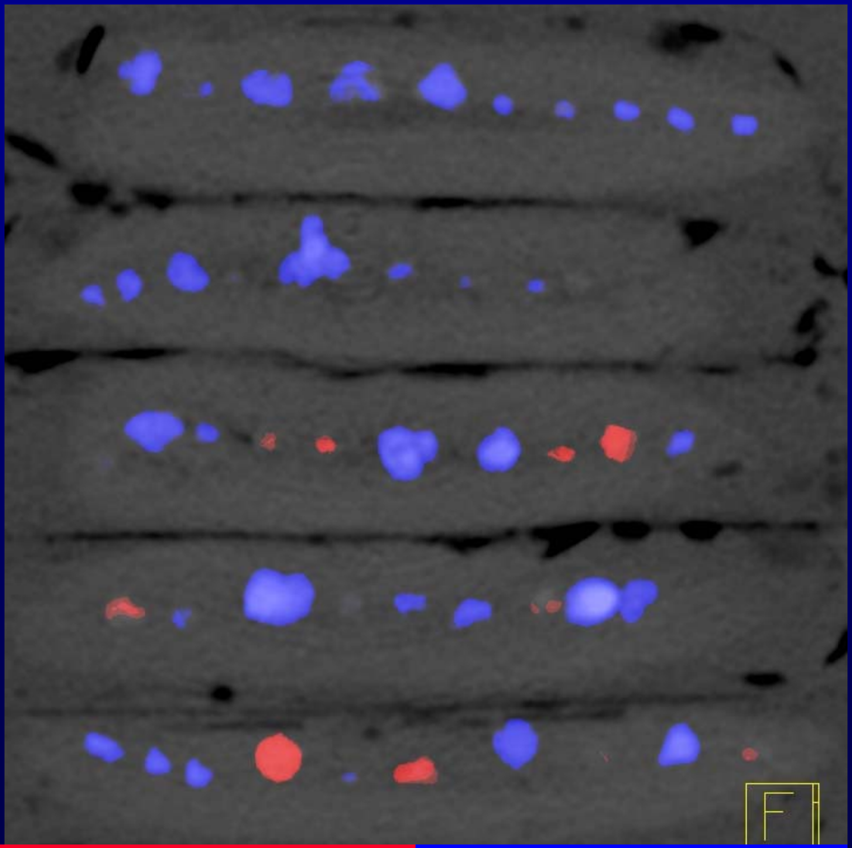
Dual-energy CT Material Decomposition



MAYO CLINIC

Dual-energy CT Material Decomposition

Stones are color coded according to composition



Uric Acid | Non-Uric Acid

Dual Source DECT – UA vs Non-UA

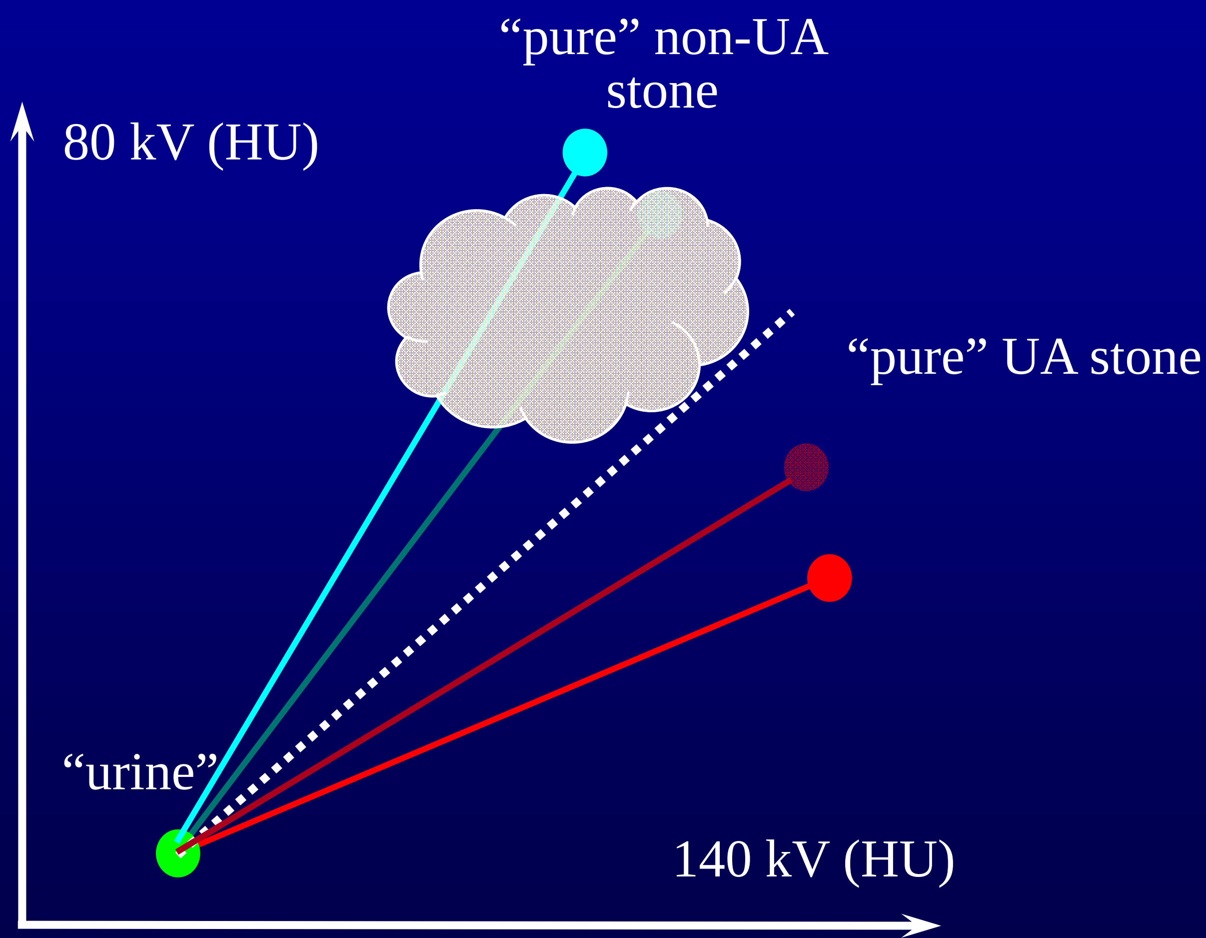
- >15 publications on stone composition differentiation using dual energy CT
- Both *in vitro* and *in vivo* studies
- High accuracy, sensitivity and specificity reported
- Used in routine clinical practice

Non-uric acid stones are most commong

- Apatite, calcium oxalate monohydrate
  - Most suitable for extracorporeal shockwave lithotripsy.
- Cystine, brushite, calcium oxalate dihydrate
  - Surgical removal (ureteroscopic lithotripsy, percutaneous, nephrolithotomy, and laparoscopic) more appropriate

MAYO CLINIC

We seek to differentiate non-UA stones by further separating the lines



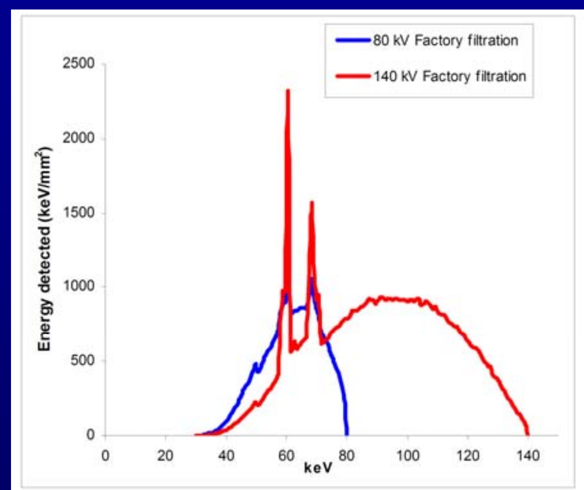
Project 1: Specific Aim 1

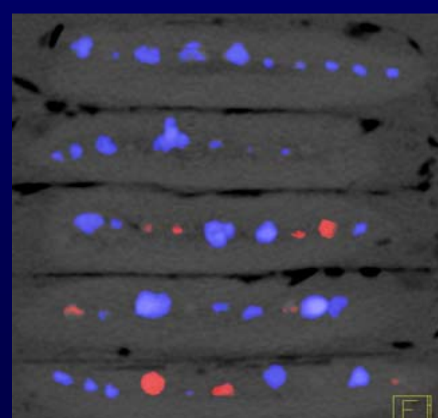
- Ex vivo development and validation of a low-dose dual-energy CT exam to quantitatively assess stone composition, volume, and morphology
- *Our working hypothesis is that quantitative measures of stone attenuation, volume, and morphology derived from low-dose dual-energy CT data will allow robust characterization of stone composition.*

Dual-energy CT stone type characterization

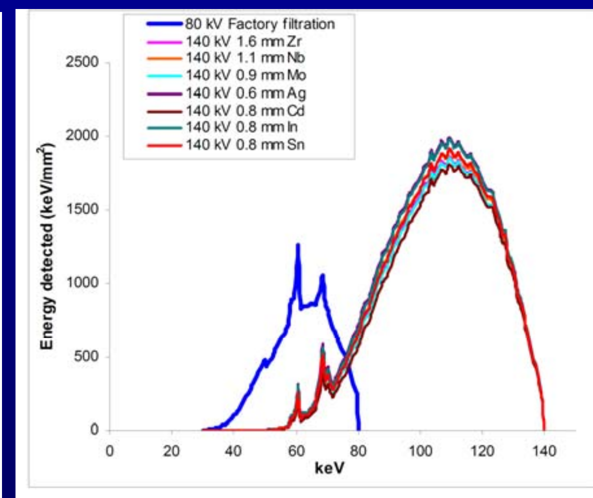
- As the overlap of the two x-ray spectra decreases
  - from "original" spectra to the one with "tin filtration"
- the lines in the low energy vs. high energy plot become more separated
- more stone types can be distinguished

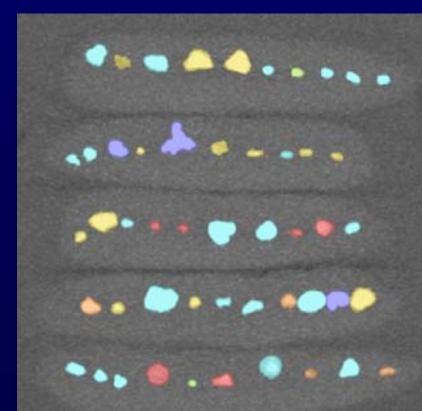
Original



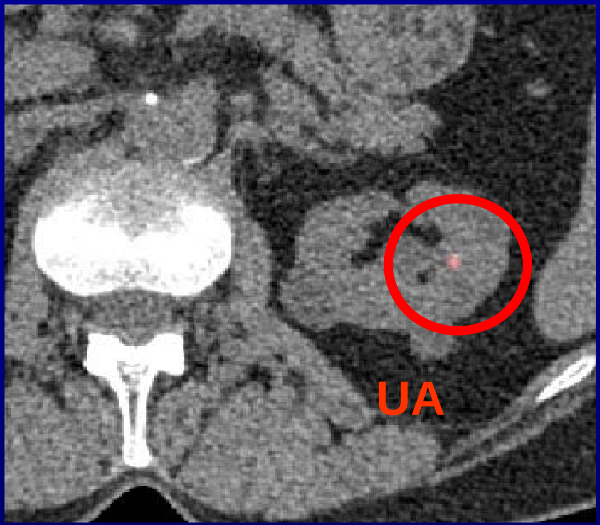


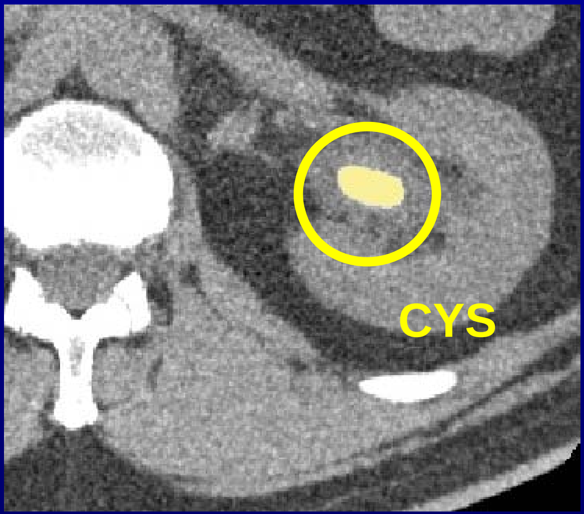
Tin filtration

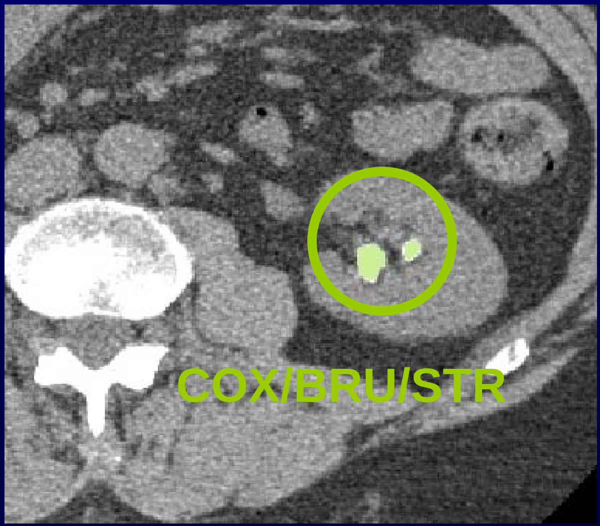


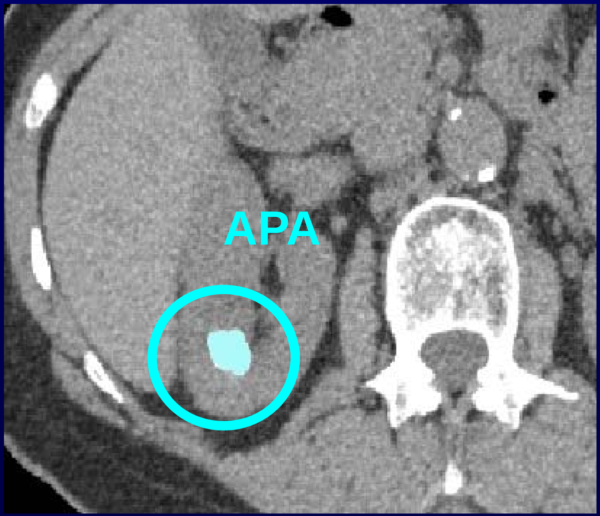


Color-coded stones from in vivo study









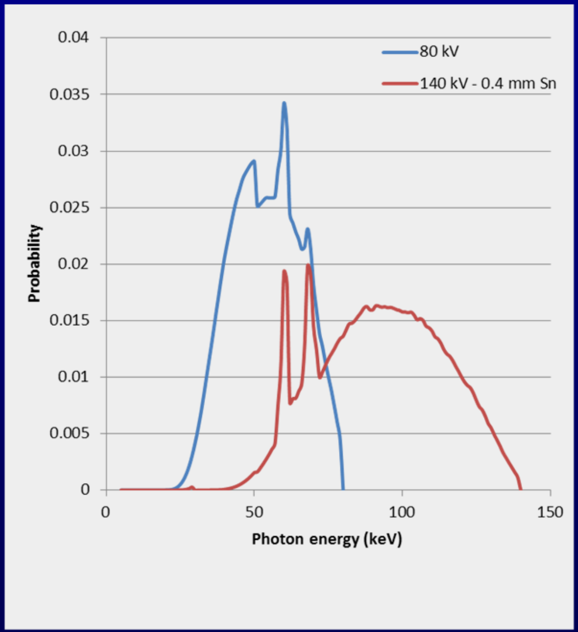
MAYO CLINIC

New CT System (Somatom Force)

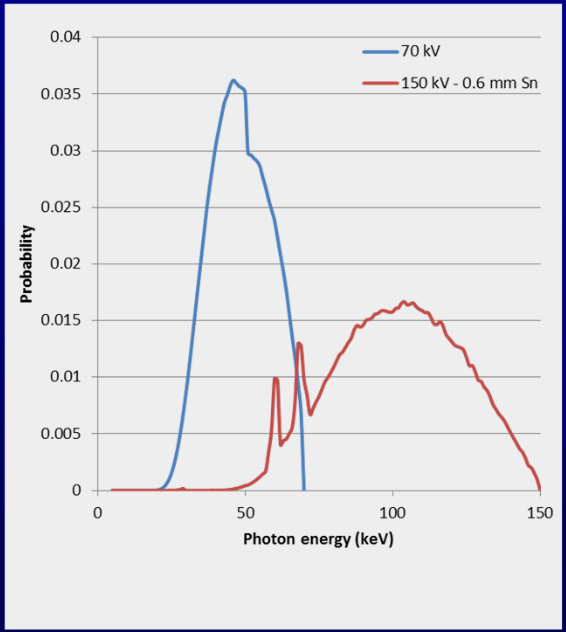
- Commercially available in 2014
  - 70 kV and 150 kV now available
  - More tin filtration available
  - Much higher tube current available

New system uses more tin filtration

Tin filtration



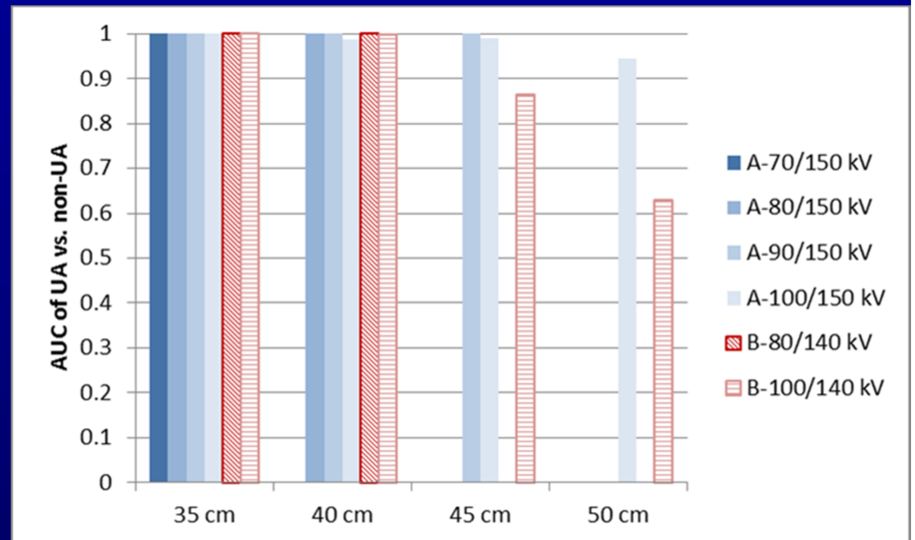
More Tin filtration

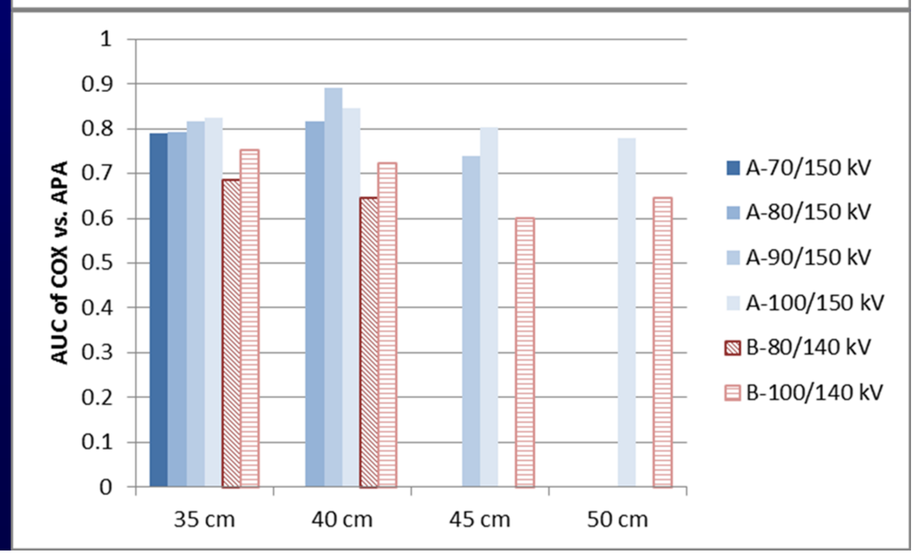


Further reduces spectral overlap

Results: Improved stone type discrimination

- With use of new scanner
  - Separation of uric acid (UA) & non-UA stones almost perfect at all patient sizes (up to 50 cm wide)
  - Discrimination of non-UA stones improved for all sizes: COX vs APA separation has AUC > 0.8





Specific Aim 2

- Develop a pre-clinical spectral CT imaging technique that can detect precursor lesions and trace elements related to the formation of kidney stones.
- *Our working hypothesis is that the use of energy-resolving, sub-mm CT detectors in conjunction with iterative reconstruction methods will provide the spectral sensitivity, spatial resolution and decreased image noise needed to detect Randall plaques, ductal plugs, and trace elements in patient tissue specimens.*

First Experiences with spectral CT scanner

- Work was supported by a Bioengineering Research Partnership grant R01 EB 016966 from the National Institutes of Health (NIH), in collaboration with Siemens Healthcare.

The described results are based on a research CT scanner that is not commercially available

MAYO CLINIC

Whole body cadaver

- World's first scan of whole human body with high-flux capable photon counting CT
- Five hours of CT scans without re-calibration
  - No ring artifacts observed !
- Image quality better than current with older detector types
- Ready now to move to in-vivo imaging

MAYO CLINIC

For additional information, please visit
http://mayoresearch.mayo.edu/ctcic