Is NEMA clinically relevent?

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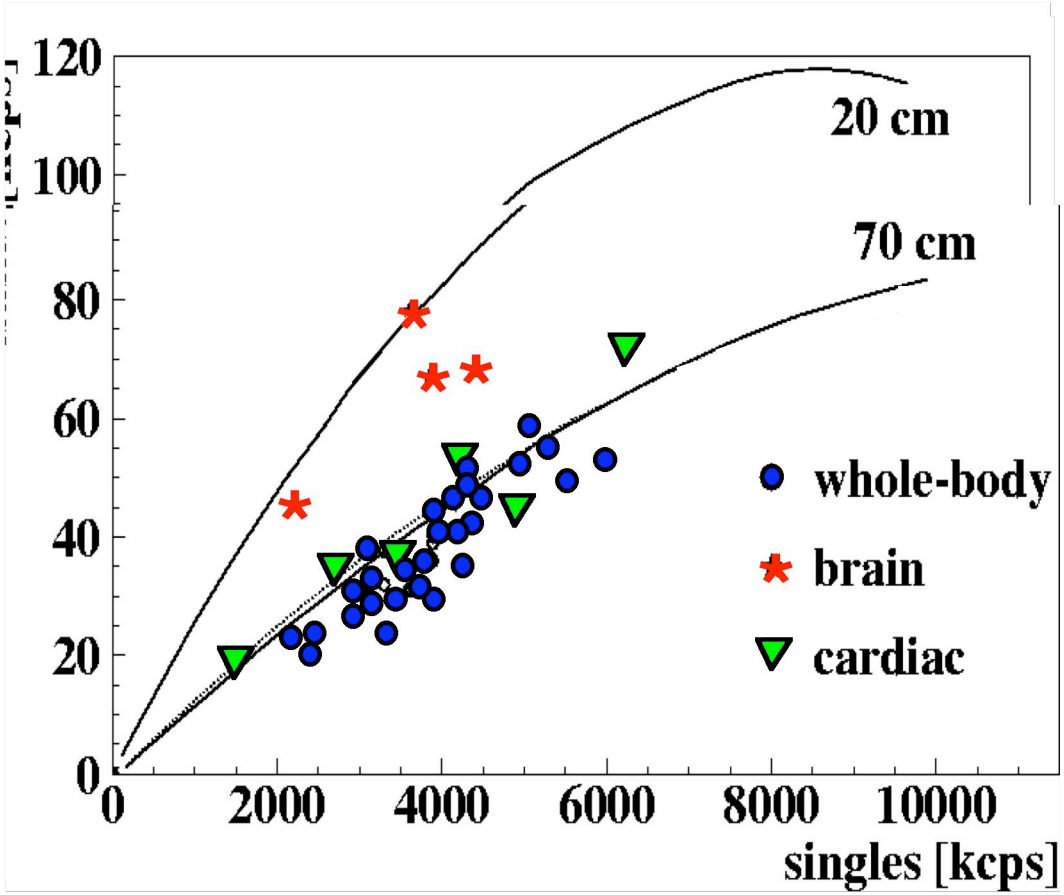
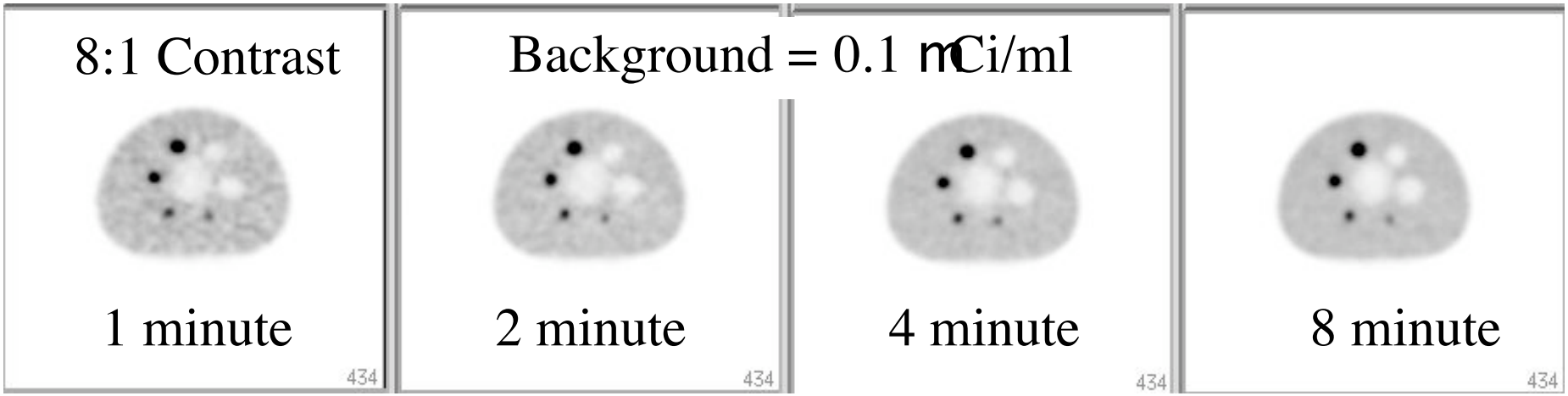
Overview

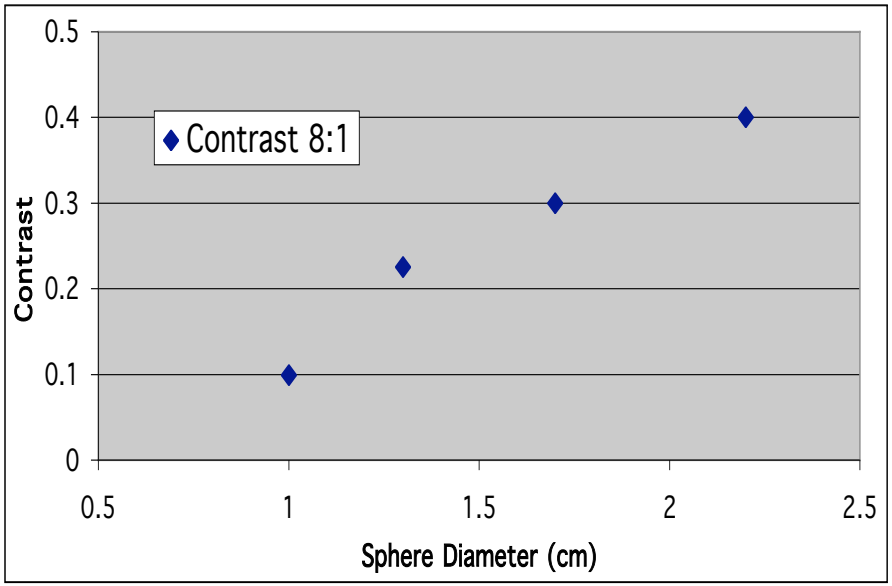
- Review of NEMA NU2
- Does NEMA need update for new technology?
- Is NEMA relevant for clinical imaging?
- Are NEMA tests relevant for quantitative clinical trials?

2001 phantom is better predictor than 1994 phantom of whole-body study count rates



Can we optimize patient protocol with image quality phantom (NEMA 2001)?





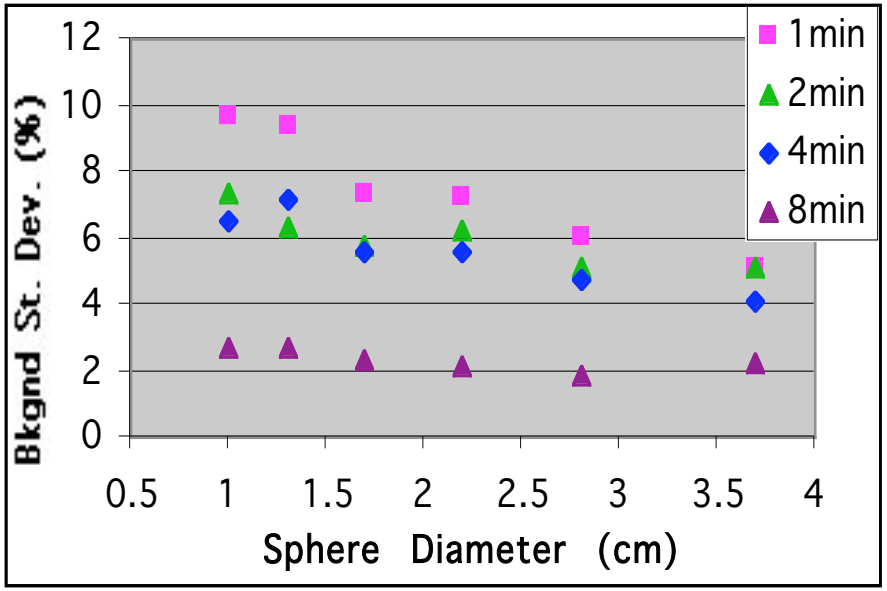
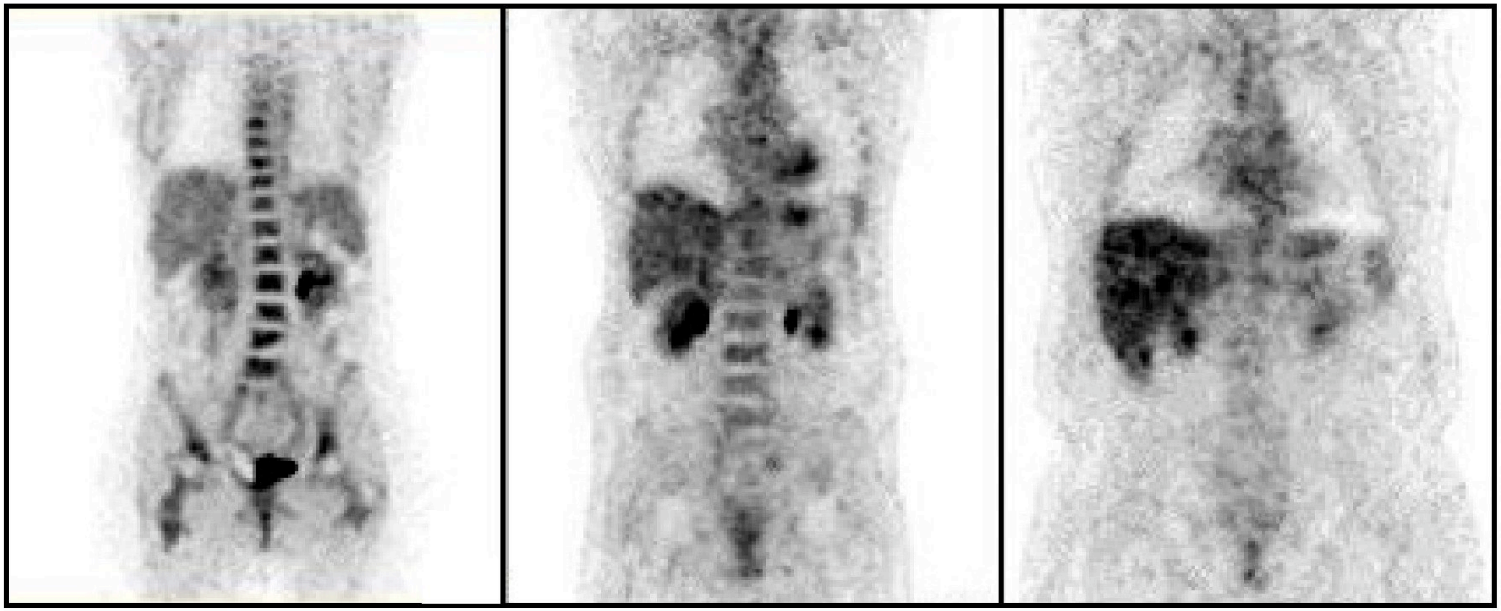


Image quality depends on patient weight

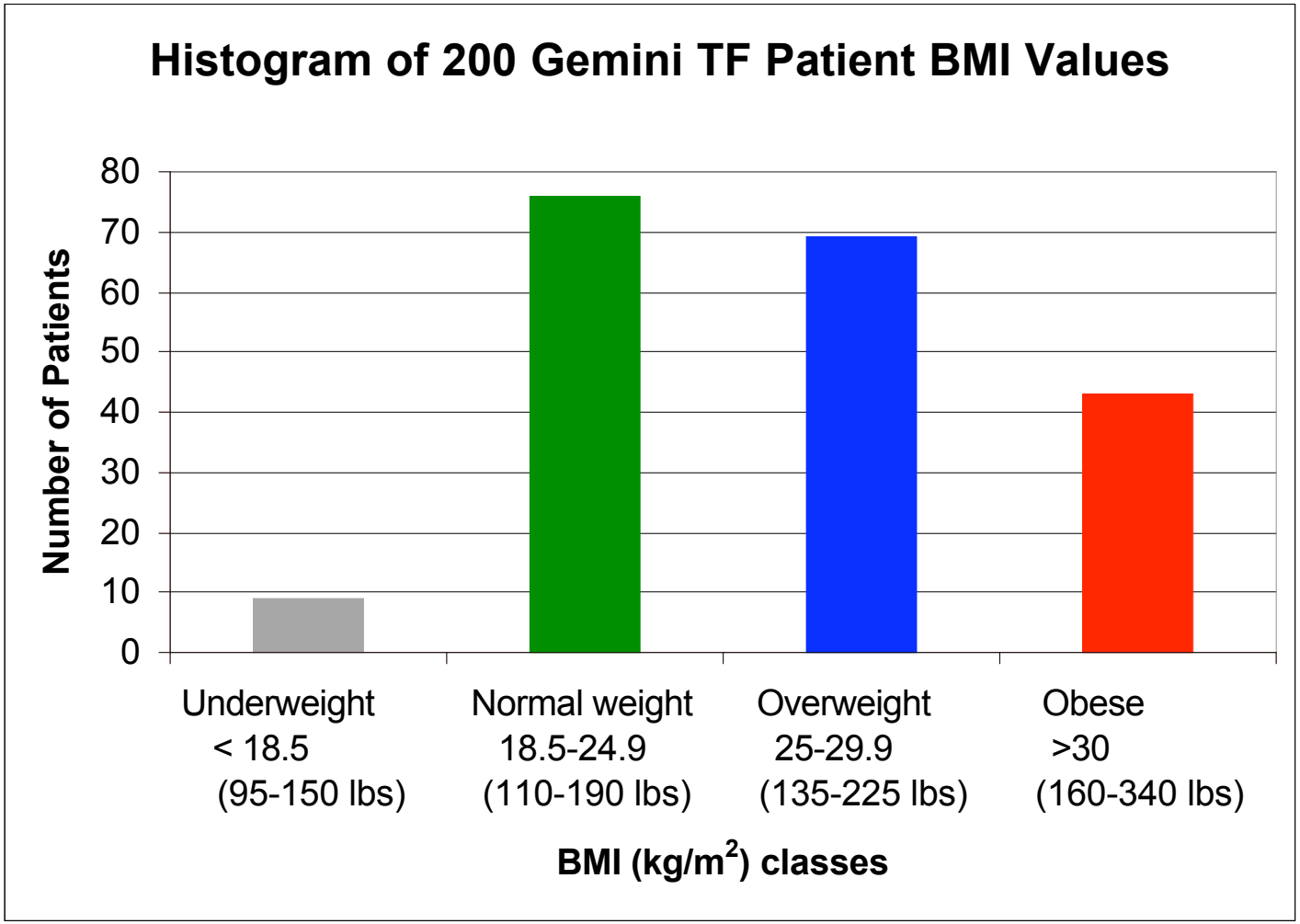
Philips Allegro



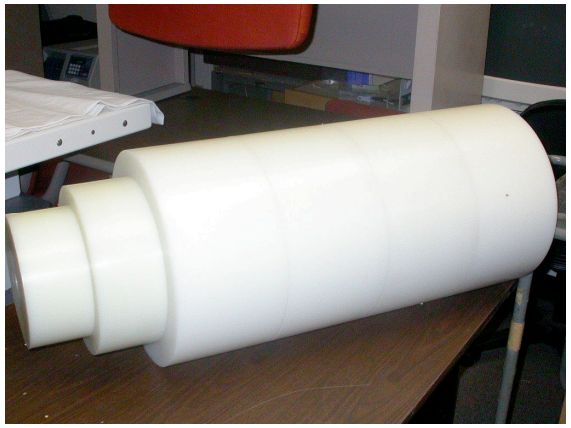
Slim 58 kg “Normal” 89 kg Heavy 127 kg

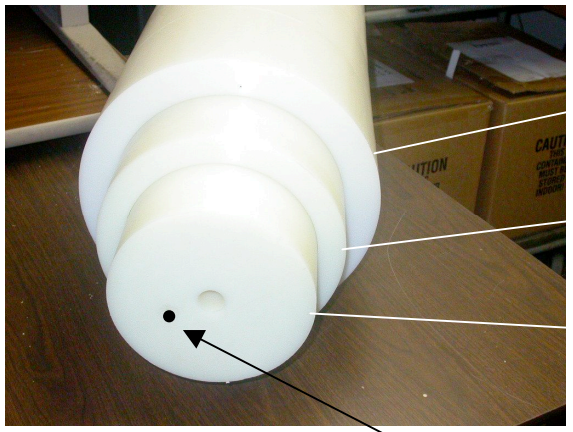
Object diameter	Relative attenuation	Peak Trues ratio	Peak NEC ratio	Peak NEC density ratio
20 cm	1	3.4	6	18
27 cm	2.2	2	2.7	4.5
35 cm	4.3	1	1	1

BMI distribution



Count-rate Measurement



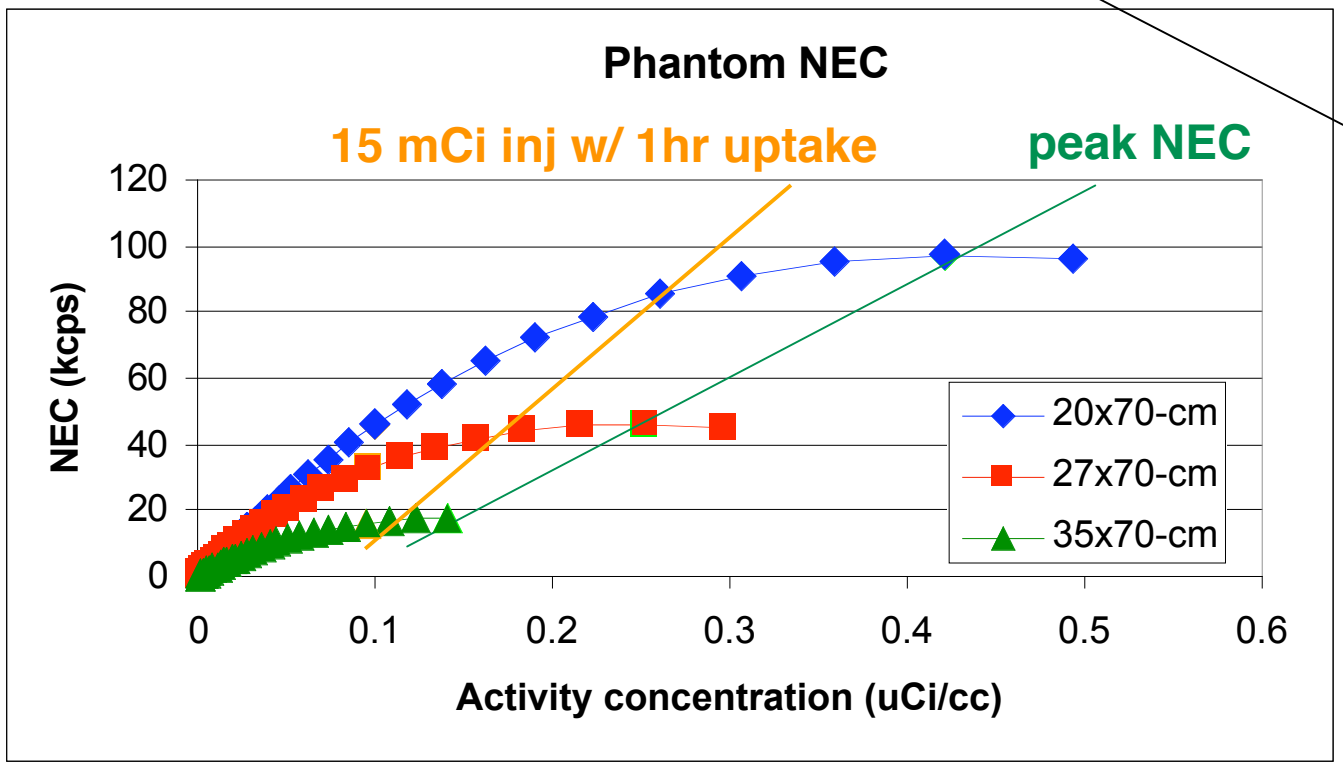


35 cm

27 cm

20 cm

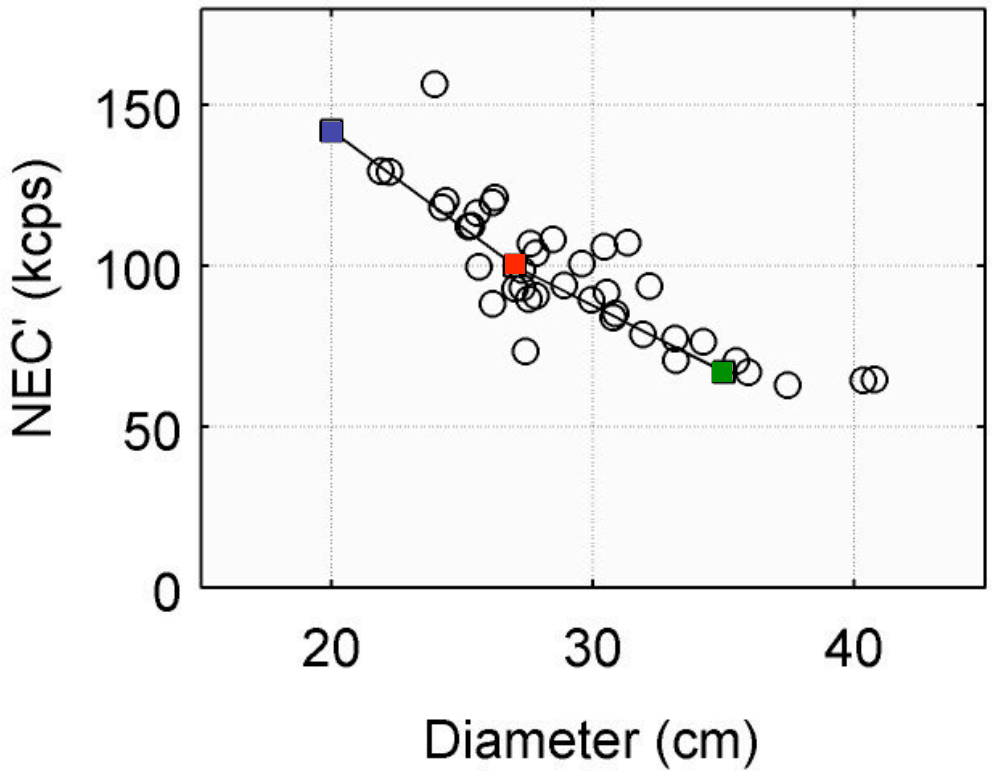
NEMA NU2



Line source activity

Gemini TF

$$NEC' = \frac{(T + Sc) \times (T + Sc)}{T + Sc + R} = \frac{(P - D)^2}{P}$$



- Patients scanned 60 min. post-injection of 555 MBq (15 mCi) of ^{18}F-FDG
- 20 cm diameter
- 27 cm diameter
- 35 cm diameter

Phantoms

Beta testing of Gemini TF TOF PET/CT

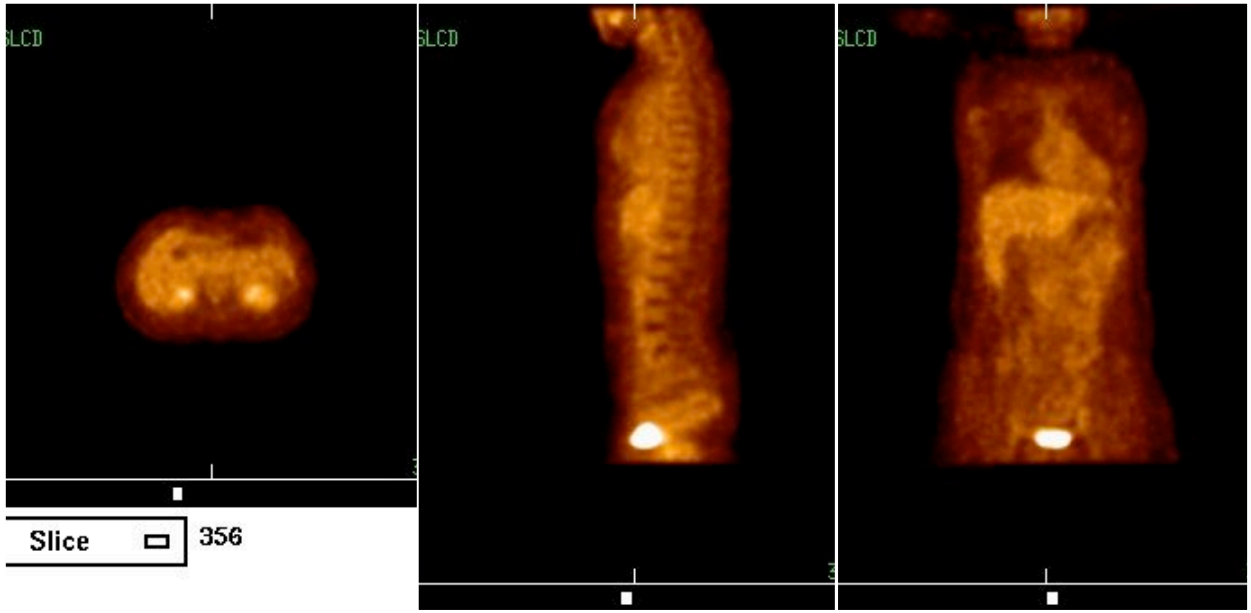
- IRB modification: scan Gemini TF following Allegro
- Gemini scan start > 2 hours post-inj, 3 minutes/bed

	crystal	E_{thresh}	Scatter	AC	Recon
Allegro	GSO 4x6x20mm^3 18cm A_{FOV}	410 keV	BG-sub	^{137}Cs	3D RAMLA
Gemini	LYSO 4x4x22mm^3 18cm A_{FOV}	440 keV	SSS model	CT	LM-EM OSEM **TOF**

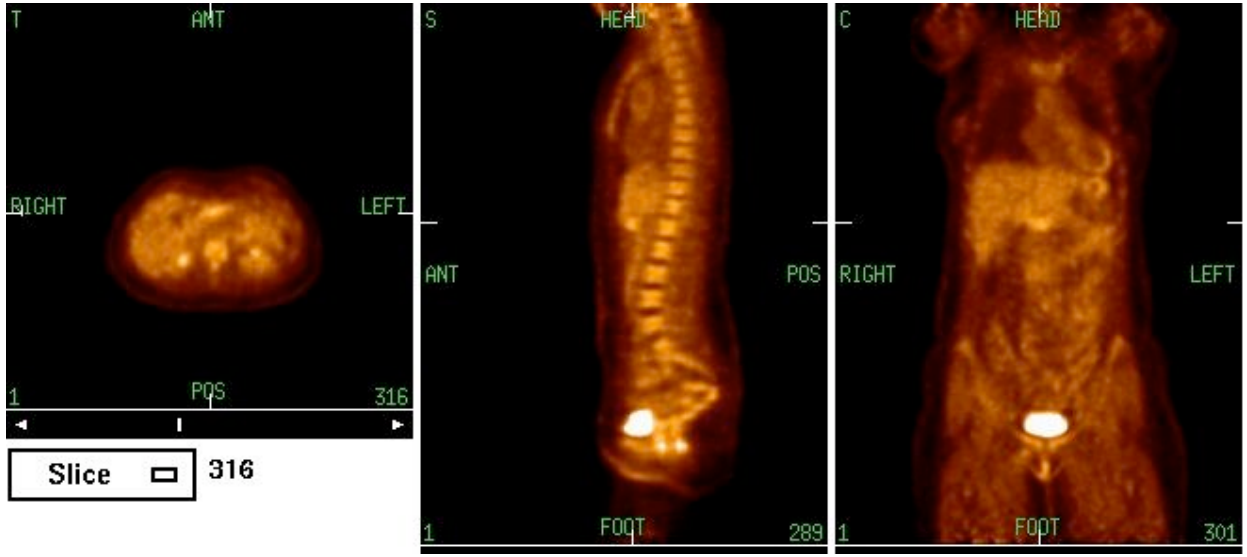
Lymphoma

39 yo woman
64 kg
BMI = 24.1

Allegro



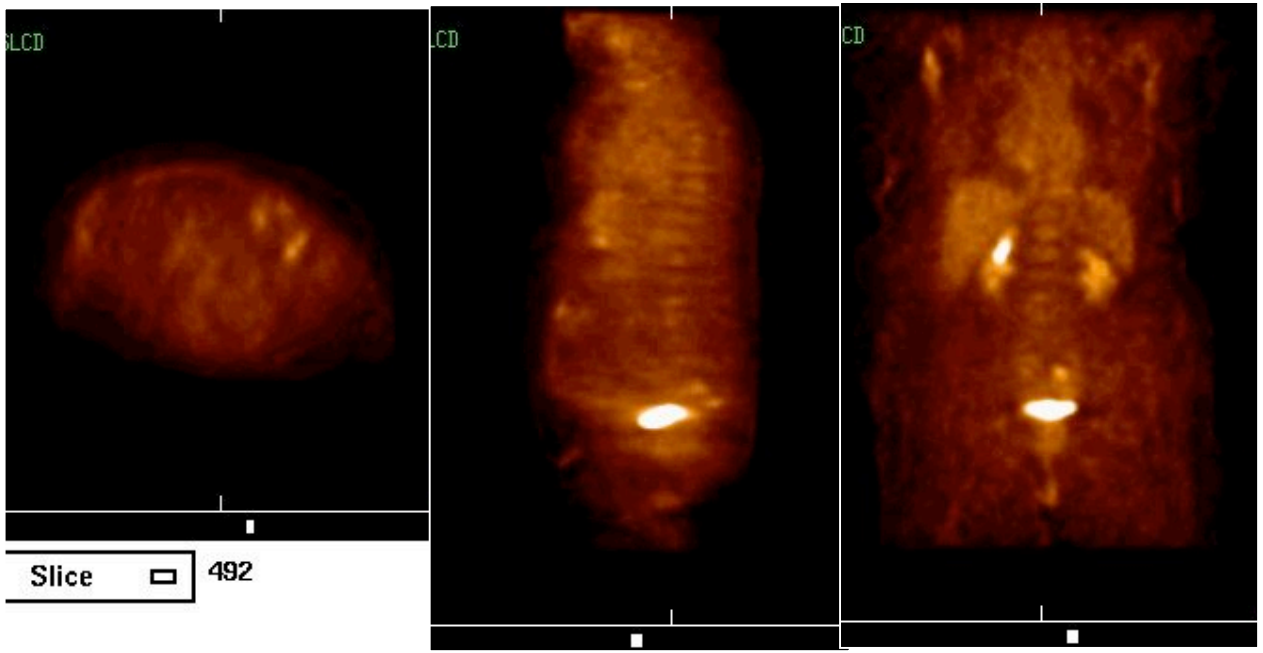
Gemini TF



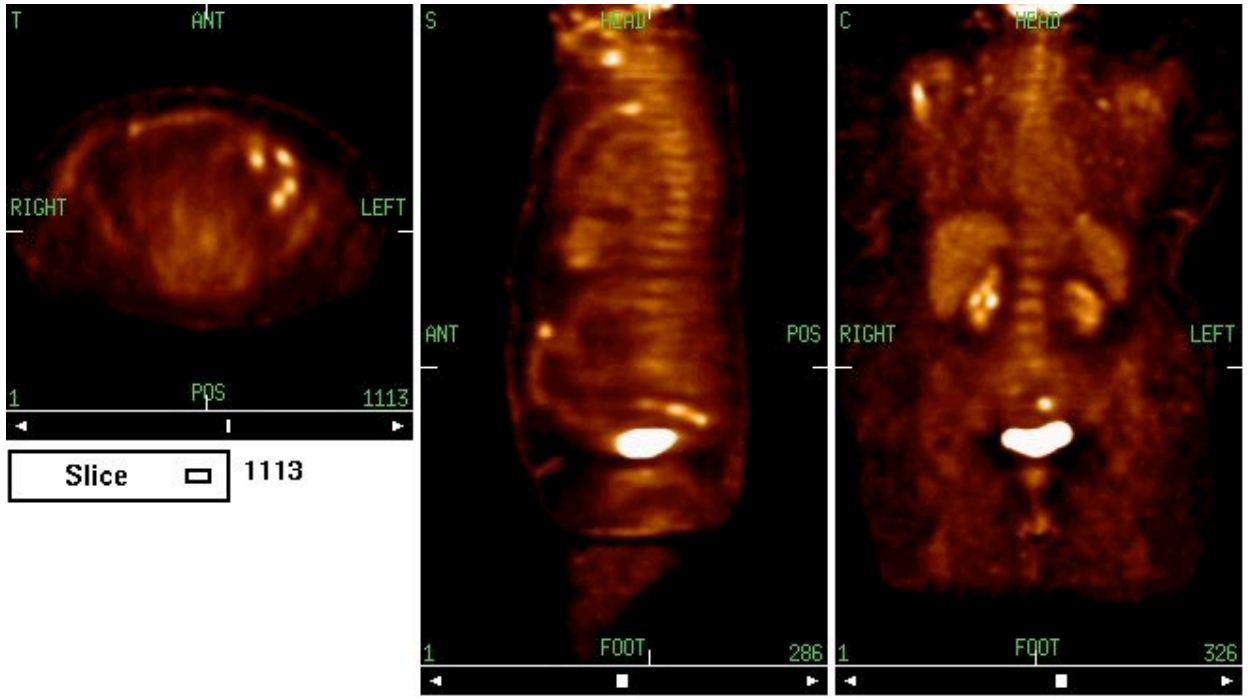
Colon cancer

73 yo woman
119 kg
BMI = 46.5

Allegro



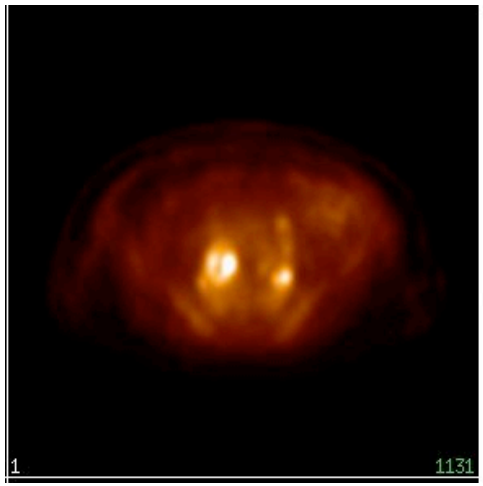
Gemini TF



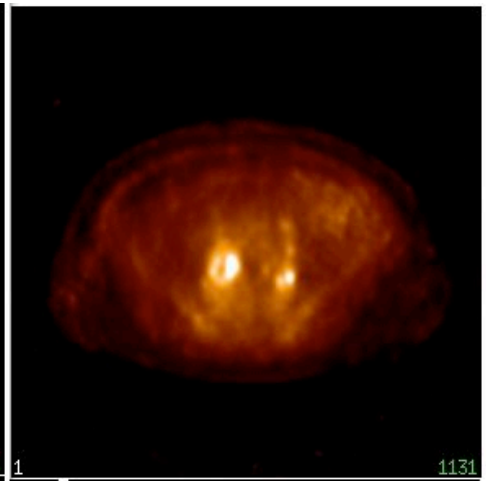
Rectal carcinoma, metastases in mesentery and bilateral iliac chains

63 yo woman
114 kg
BMI = 38.1

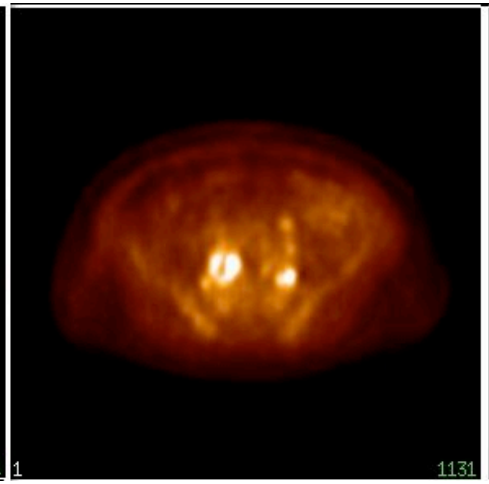
Data acquired with Gemini TF
Reconstructed with 4 algorithms



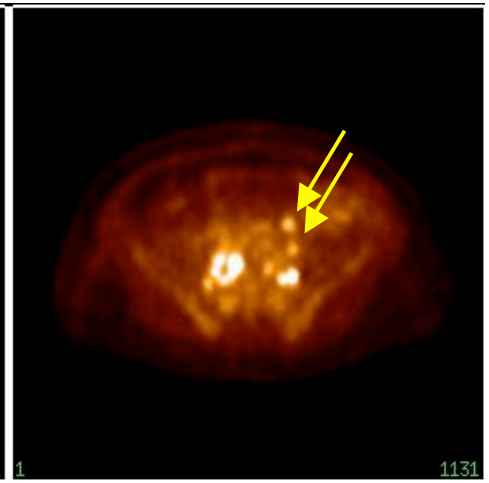
3D Ramla
non-TOF



LOR Ramla
non-TOF

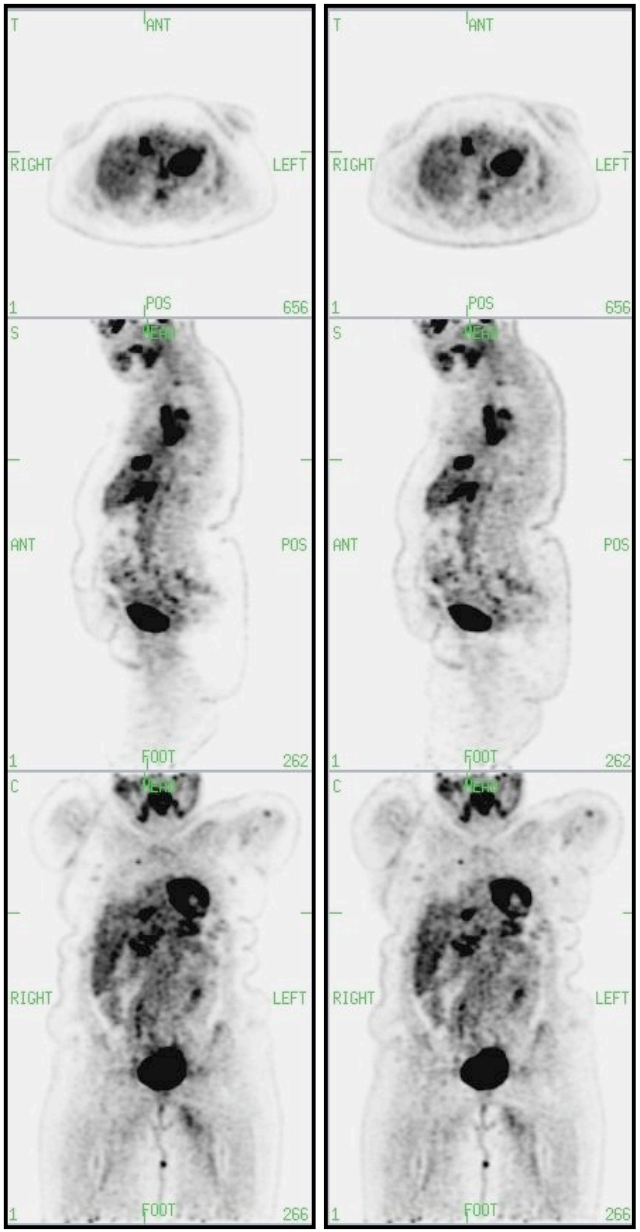


List-Mode EM
non-TOF

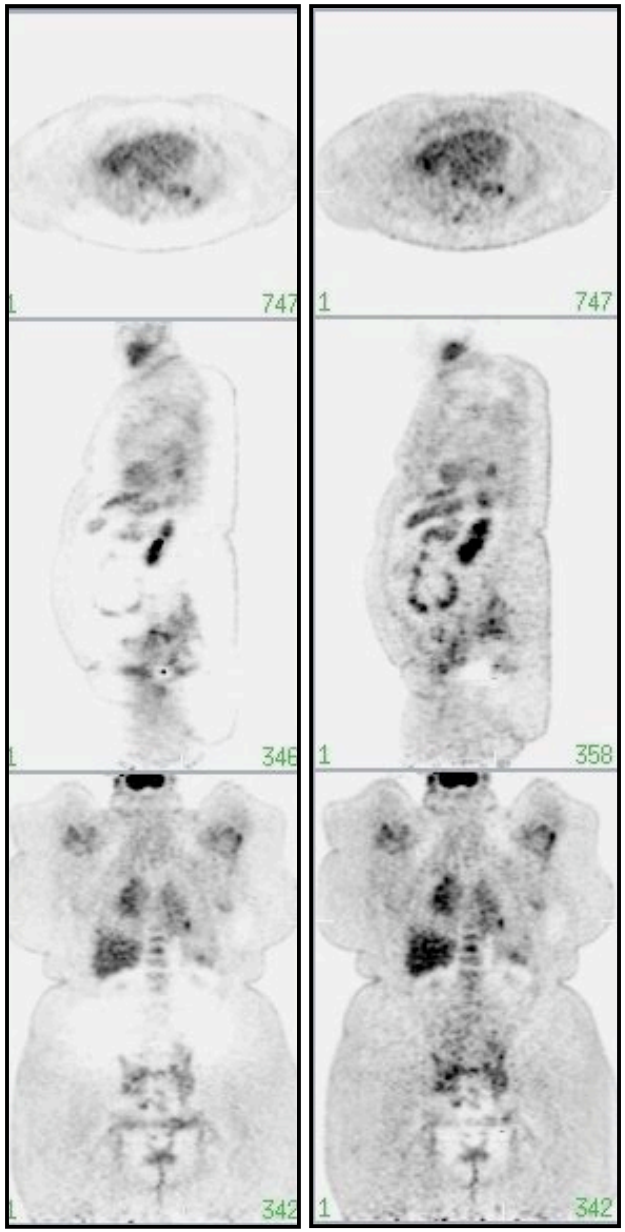


List-Mode EM
TOF

Philips Gemini TF



SSS TOF-SSS



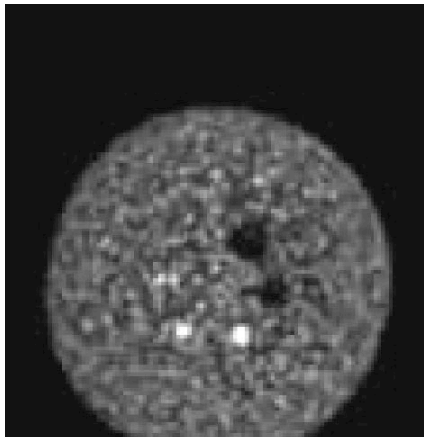
SSS TOF-SSS

Is the total (image) equal to the sum of its parts?

Spatial resolution + SF + Sensitivity + ……. = ?

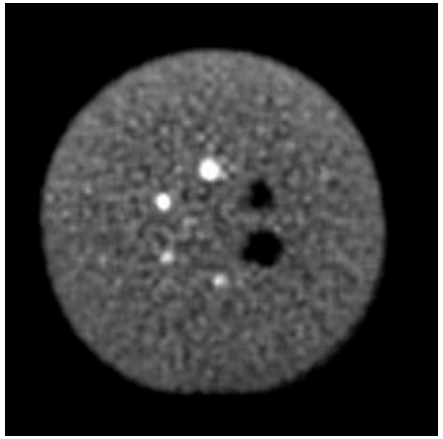
Gemini TF (LYSO)

4.8 mm 27% (440 keV) 6.6% 700 ps



LaPET (LaBr)

5.5 mm 18% (485 keV) 6% 420 ps



Same reconstruction
TOF LM-EM

Are the NEMA tests relevant for clinical trials?

PET/CT Applications and Challenges

Primarily for Cancer Imaging -- works very well

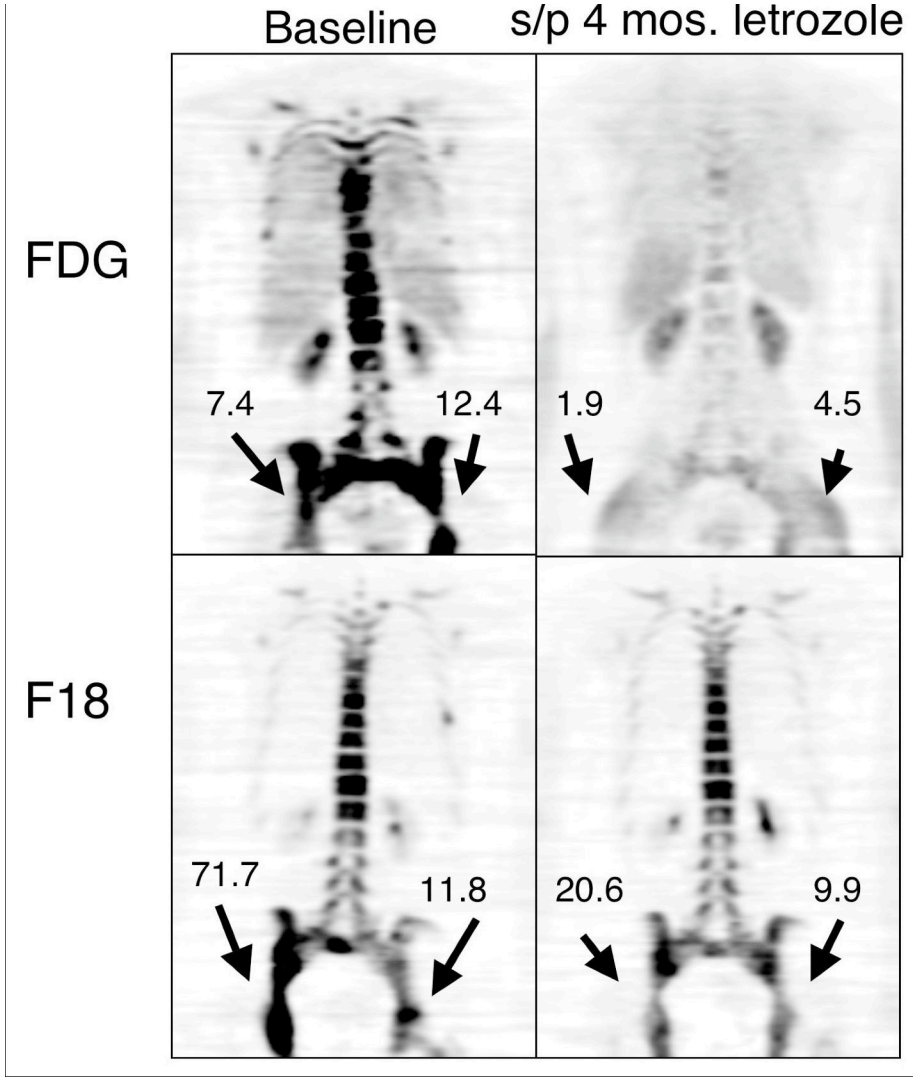
- Diagnostic imaging and staging for cancer

Expanding Areas -- with significant challenges

- Radiation treatment planning using PET and CT
- Cardiac imaging
- Assessment of therapeutic response

Quantitative Assessment of Response to Therapy

Change in SUV measures of FDG and fluoride incorporation for bony metastases from breast cancer before (left) and after hormonal therapy (right)

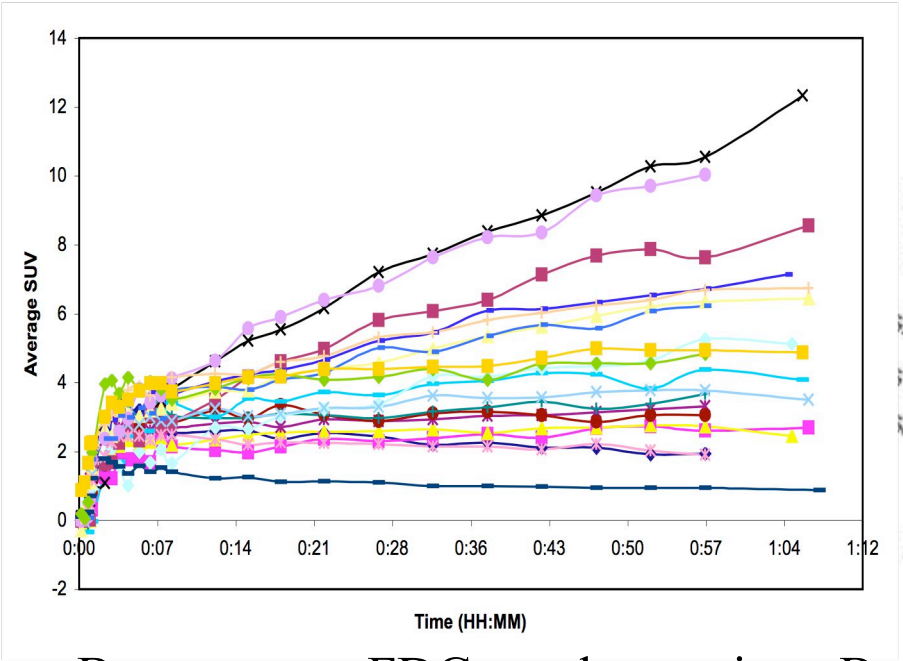


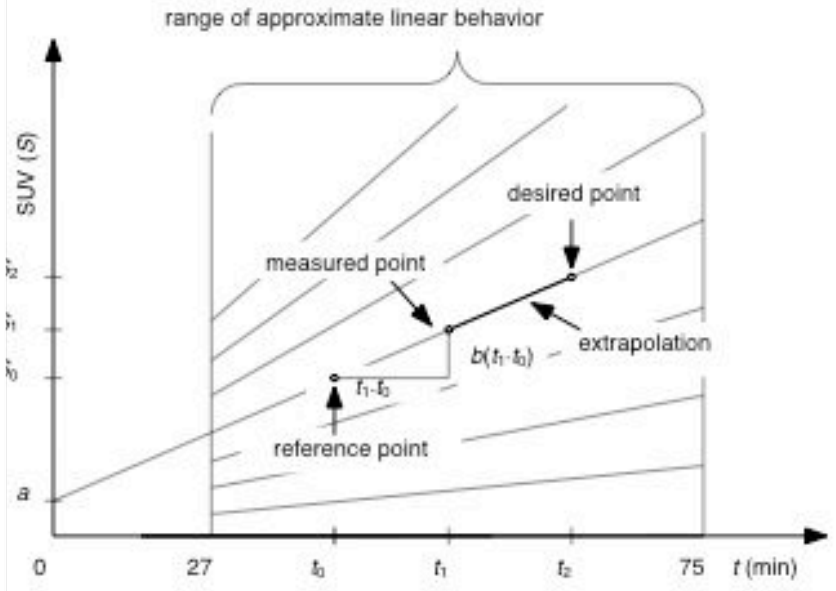
Courtesy David Mankoff U of W

Quantitative Assessment of Response to Therapy

"Consensus Recommendations for the Use of 18F-FDG PET as an Indicator of Therapeutic Response in Patients in National Cancer Institute Trials" *JNM 47(6):1059, 2006*

- considered issues with patient prep and scan protocol
- issues with multicenter comparisons not resolved





Breast tumor FDG uptake vs. time Beaulieu JNM 44(7):1044, 2003

What Affects PET Image Quantitation?

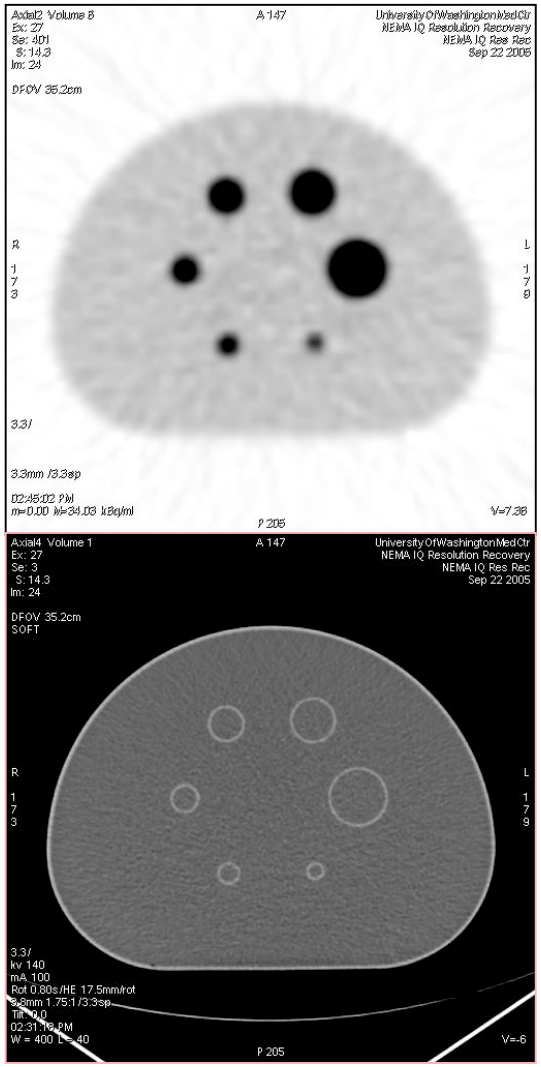
Physical sources of error

- Attenuation
- Scattered and Random coincidences
- detector efficiency variations, scanner dead-time

Sources of variability

- Patent Specific
  - Biological changes
  - Lesion size (partial volume effect)
  - Patient motion
- Imaging protocol
  - patient preparation
  - uptake period and environment
  - scan protocol: amount of FDG injected, scan duration, 2D or 3D mode, PET vs. CT order
- Processing specific
  - Reconstruction Method
  - Image smoothness vs. resolution tradeoff
  - Standardized Uptake Value (SUV) calculation
  - Display and analysis methods

SNM ^{68}Ge Phantom : characterize recovery coefficient vs. sphere diameter and reconstruction method



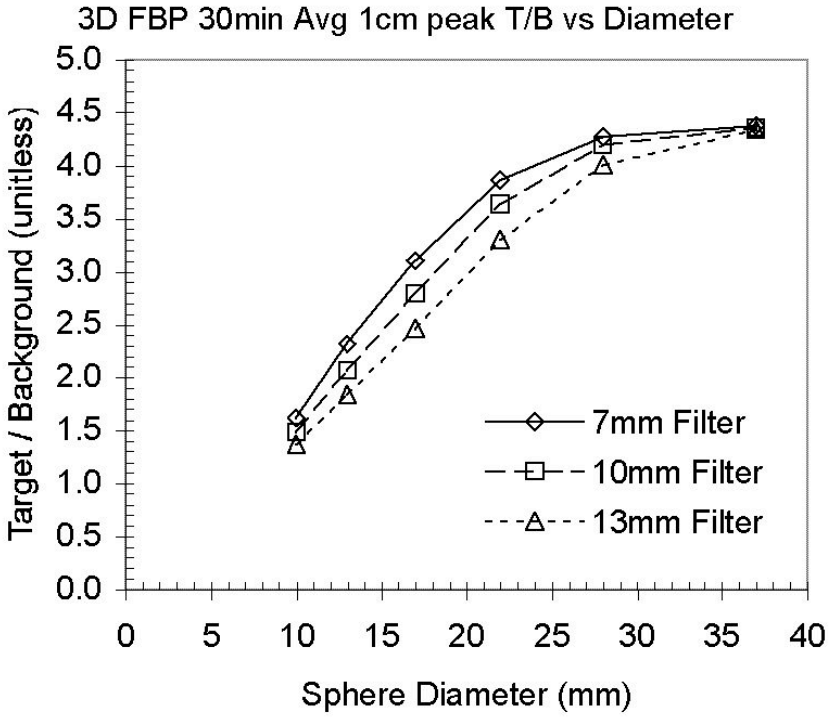
Investigate most important effects:

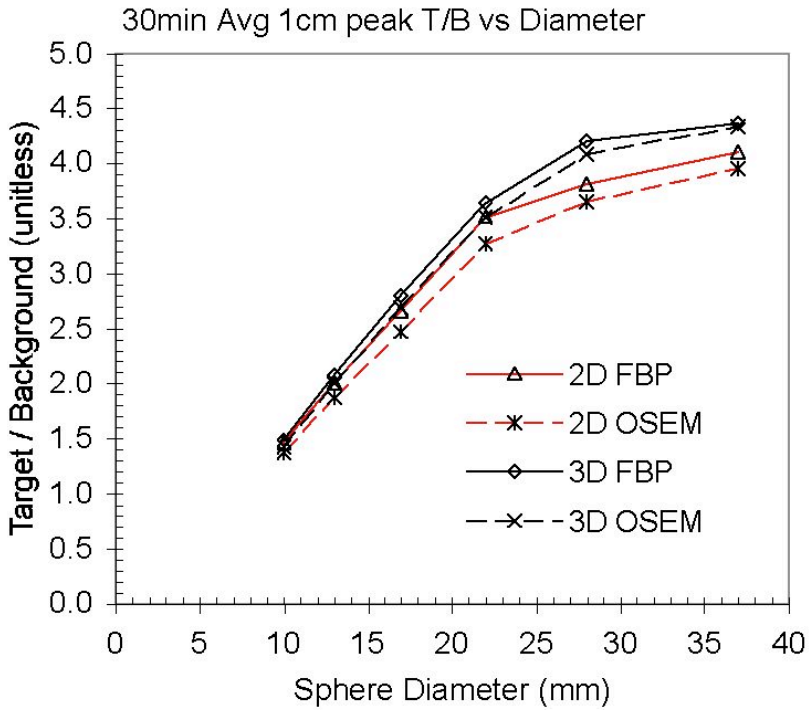
- mean and max recovery coefficient
- sphere diameter
- reconstruction method
- Smoothing

Modified NEMA NU-2
Image Quality Phantom

Sphere diameters:
1.0, 1.3, 1.7, 2.2, 2.8, 3.7 cm

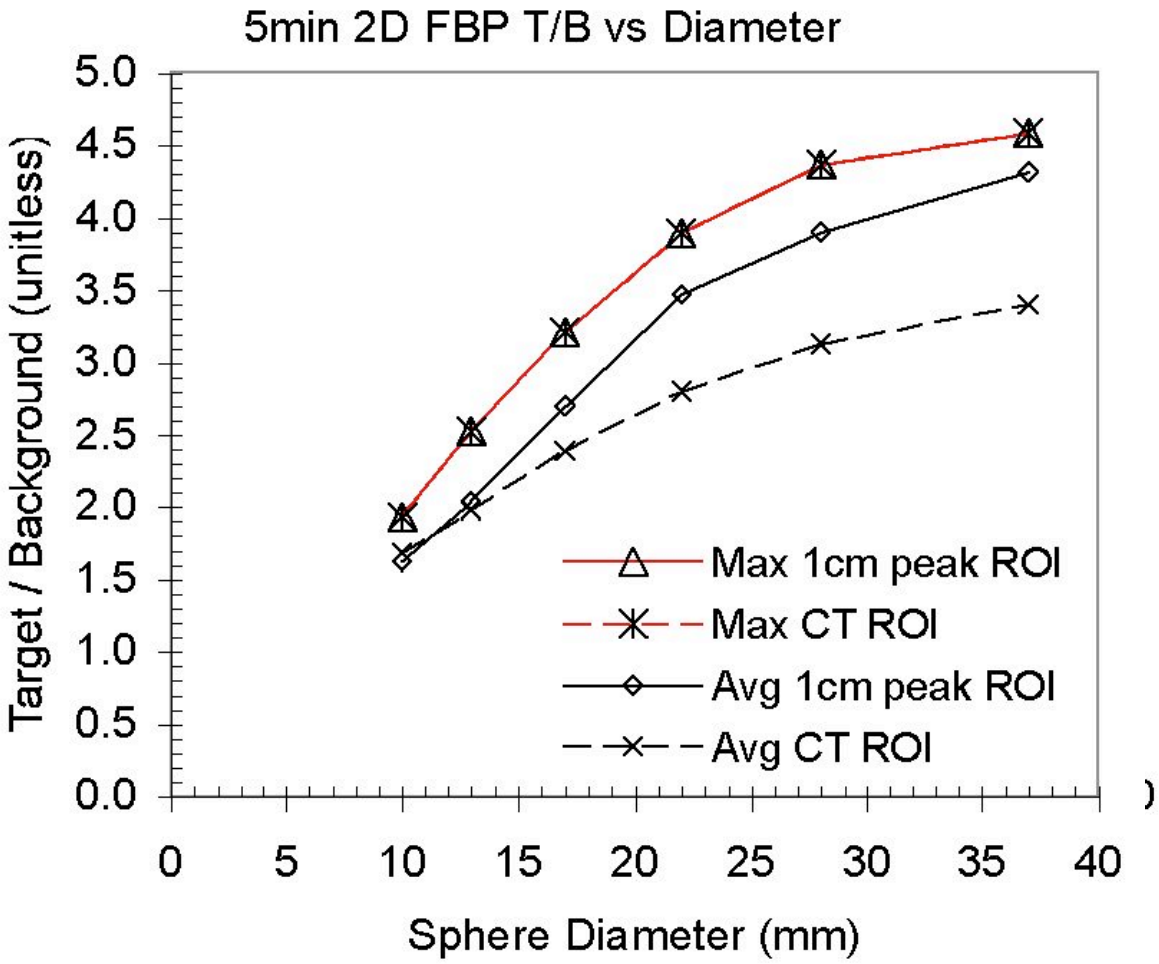
Contrast depends on reconstruction and filter





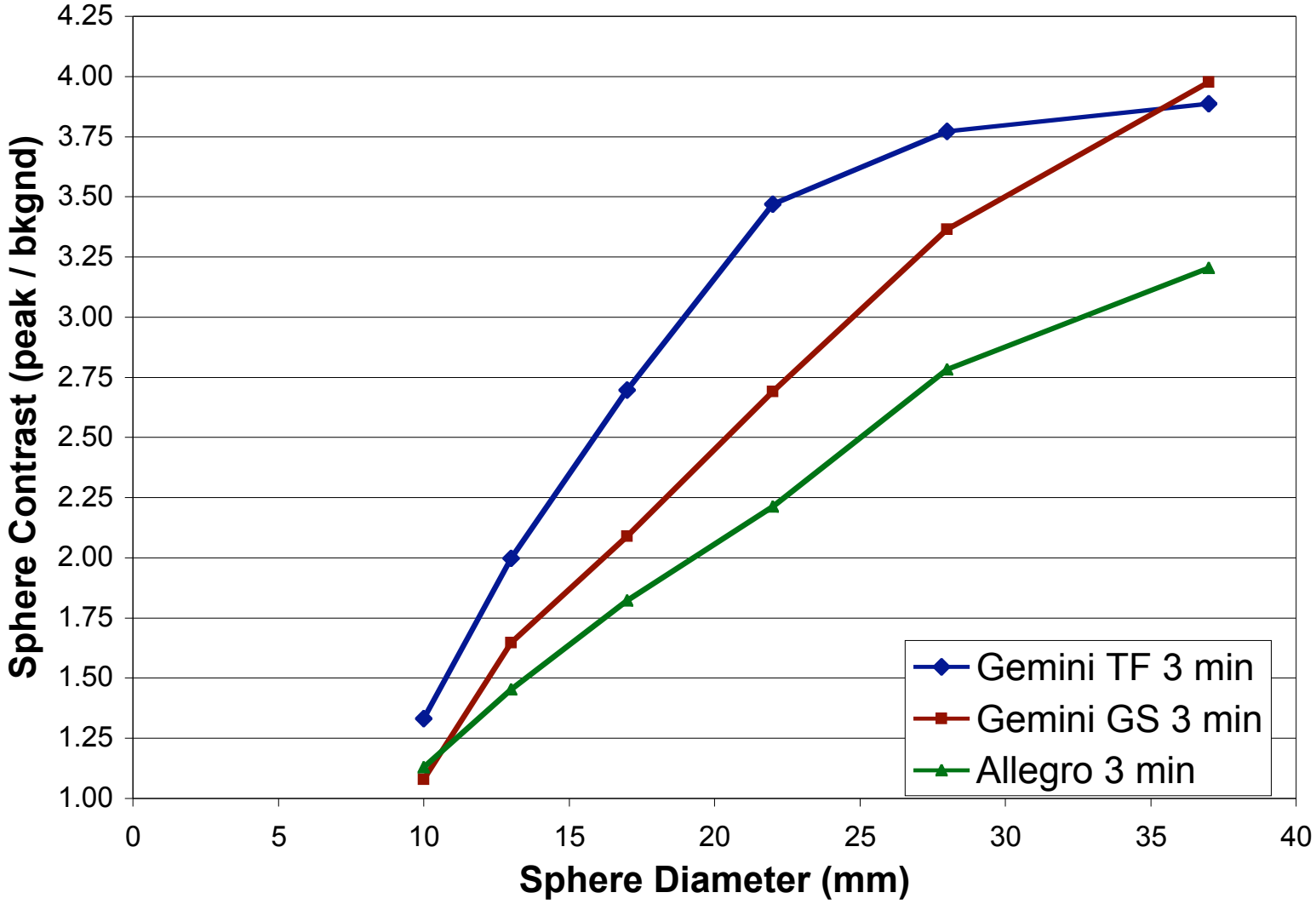
GE Advance, U. Wash

Contrast depends on ROI



GE Advance, U. Wash

Comparison of 3 scanners



PET Core Lab

ACRIN™ American College of Radiology Imaging Network

- Use of imaging data as an *in vivo* biomarker requires that quantitative, semi-quantitative and qualitative endpoints reliably reflect disease status

- Achieved by standardization of image acquisition and processing at participating sites
  - Site qualification
  - SOPs
  - Timely QA of incoming data

- Achieved by image processing and analysis at central facility under tightly controlled conditions

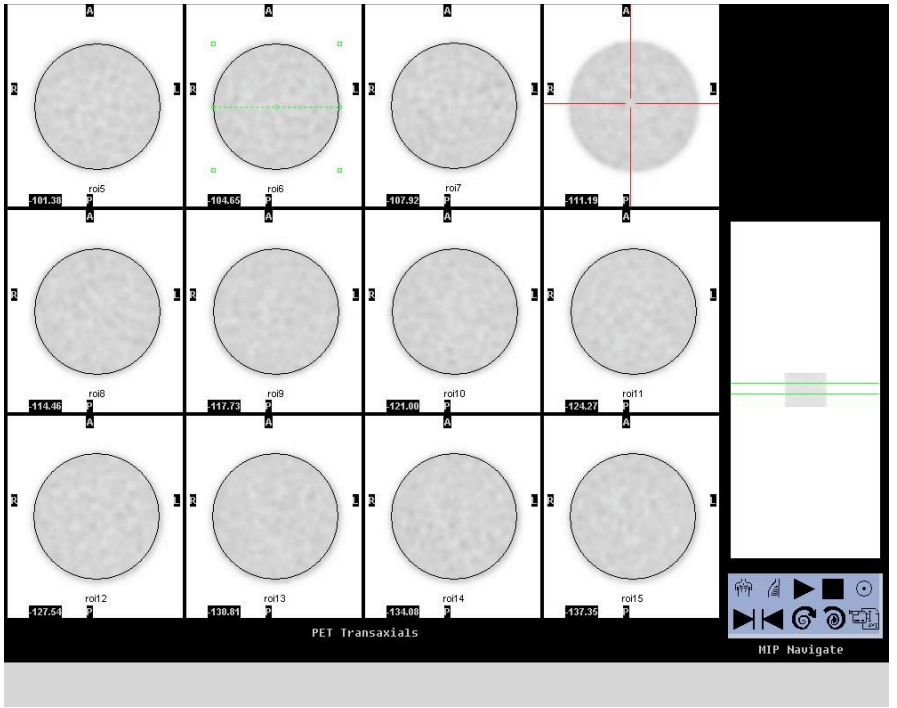
ACRIN PET Credentialing

- *Submit the following for every gantry:*
  - Uniform phantom data set with SUVs
    - Fully corrected
    - Non-attenuation corrected
    - Transmission scan
  - Two anonymized wholebody patient scans
    - Fully corrected
    - Non-attenuation corrected
    - Transmission scan
  - PET qualification application form

Measuring phantom SUVs

- "…scan the phantom with the same protocol used for patient imaging. Reconstruct the images with the same algorithm and filters used for patient imaging. Draw a circular or elliptical region of interest (ROI) covering most of the phantom's interior over all slices. Measure and report the average SUV and standard deviation in the PET Instrument Technical Specification form. **The expected SUV for the uniform phantom is 1.0 and the acceptable range is 0.90 to 1.1.**

Summary of Average SUVs of Accepted Cylinders



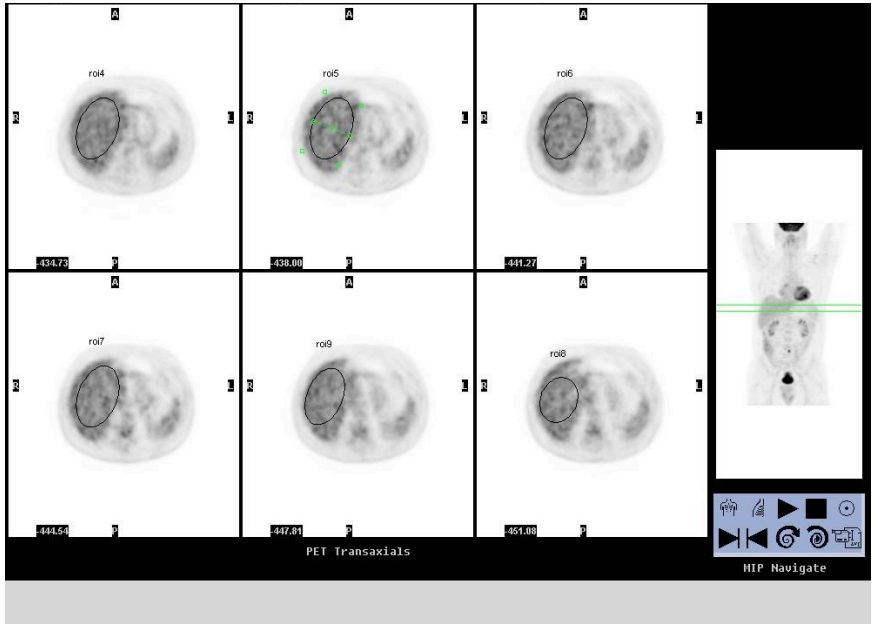
Model	# Sites	Average	St. Dev
Siemens Biograph PET/CT	32	0.98	.04
GE Discovery LS PET/CT	11	1.00	.05
GE Discovery ST PET/CT	28	1.01	.04
Philips Allegro PET	5	0.98	.09
Philips Gemini PET/CT	7	0.95	.05

- Of the first 53 sites to apply for PET qualification, 11% failed because of PET camera calibration problems.
- Numerous other sites had cylinders that initially failed due to incorrect information entered in the DICOM header

Most Common Mistakes

- Incomplete submission (data or form)
- Data transmission problems (empty headers)
- Wrong weight for phantom
- Clock offsets
- Anonymization problems (over or under)
- Ge-68 cylinder-related problems

Summary of Average Liver SUVs in Test Cases



Model	# Cases	Average	St. Dev
Siemens Biograph PET/CT	59	2.33	0.42
GE Discovery LS PET/CT	23	2.15	0.33
GE Discovery ST PET/CT	47	2.26	0.40
Philips Allegro PET	8	1.73	0.83
Philips Gemini PET/CT	12	1.78	0.46

Summary

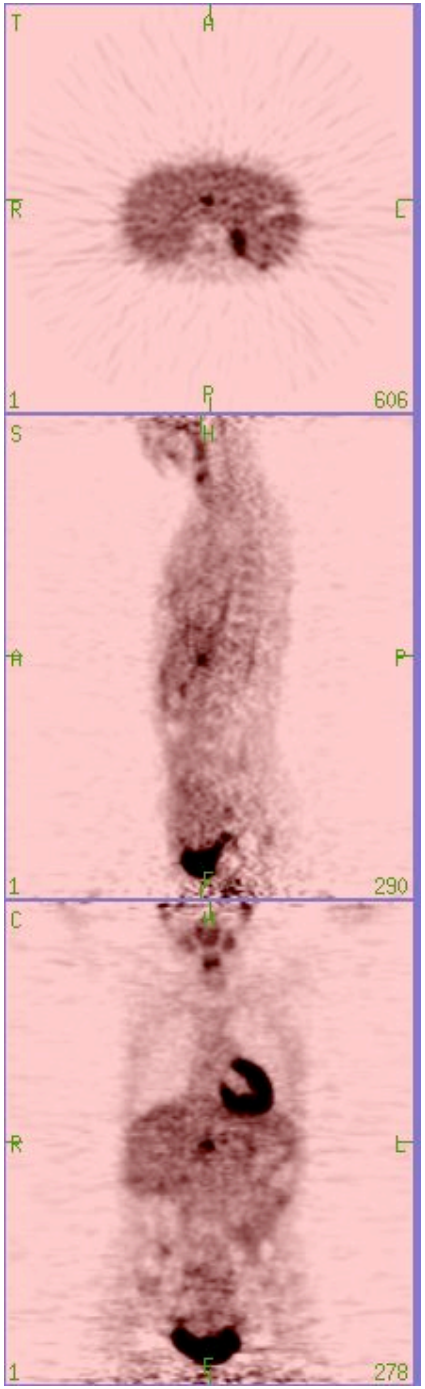
• Optimization of scanner
- adjust acquisition and reconstruction parameters - define clinical protocols

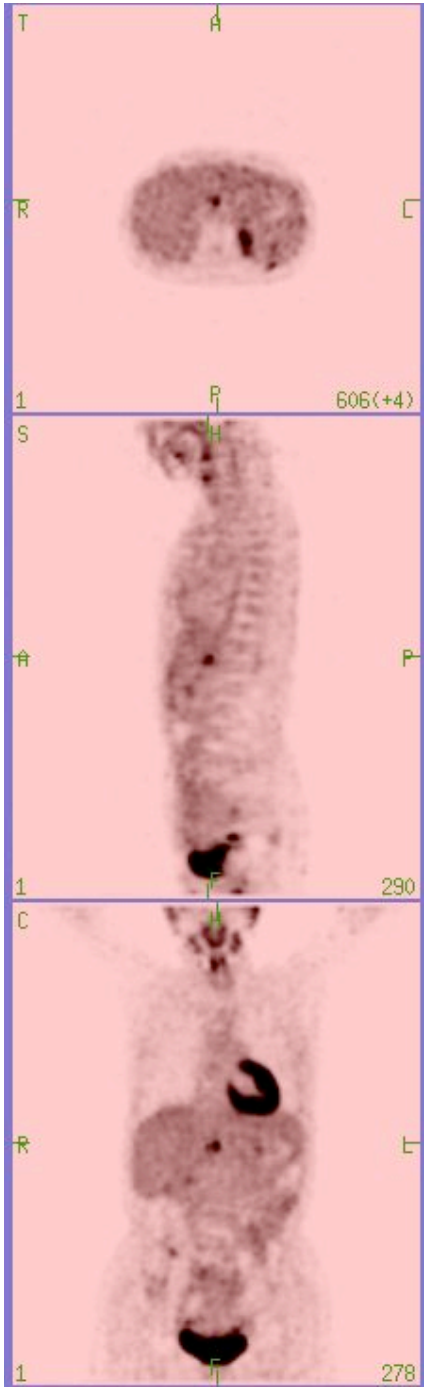
• Difficult to predict performance for variety of patient BMI and protocols with limited number of phantoms and tests - task specific

• Quantification of multi-center clinical trials not resolved
- instrument variability
- site/user variability
- patient/biology variability

Filtered Backprojection

Filter trades off resolution and noise





Iterative reconstruction

more accurate modeling of physical effects, including noise