AAPM Initiatives in Quantitative Imaging

John M. Boone, Ph.D., FAAPM, FSBI, FACR

Chair, AAPM Science Council
Chair, *Ad Hoc* Committee on Quantitative Imaging
Chair, TG on QI in CT

Professor and Vice Chair (Research) of Radiology
Professor of Biomedical Engineering
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Disclosures:

- Varian Imaging Systems, Paid Consultant
- Artemis, Paid Consultant
- Varian Imaging Systems, Research Funding
- Hologic Corporation, Research Funding
- Fuji Medical Systems, Research Funding

The AAPM Quantitative Imaging Initiative

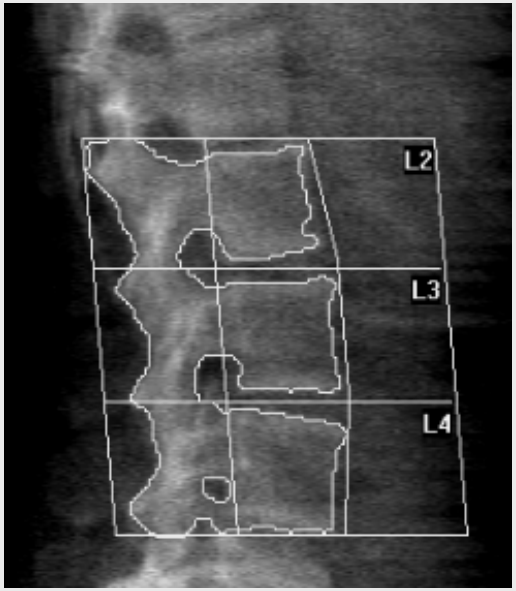
- Introduction to QII
- AAPM activities in QI
- Trans-modality efforts
- Positron Emission Tomography (PET/CT)
- Magnetic Resonance Imaging (MR)
- Computed Tomography (CT)
- Summary

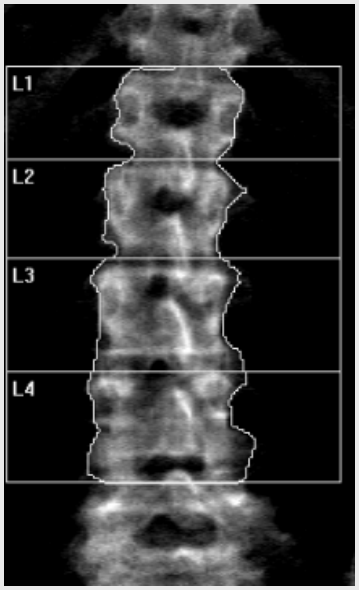
Currently used Image-based Quantitative Metrics

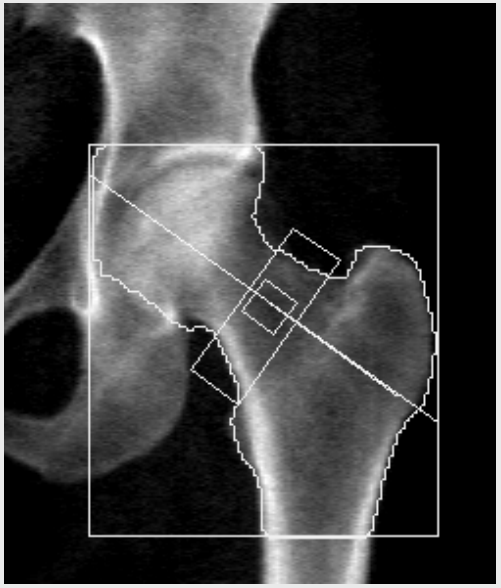
Bone mineral density analysis

RISK

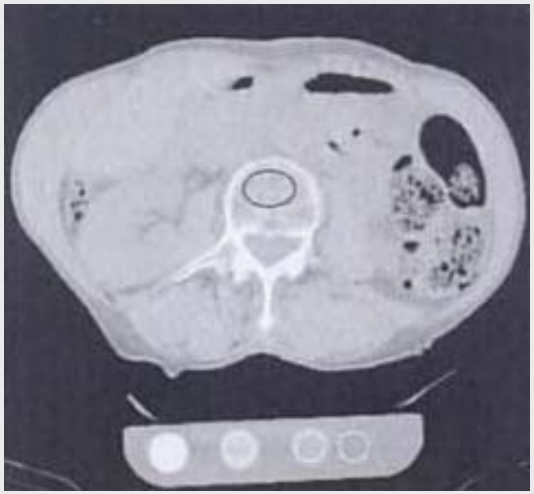
2D

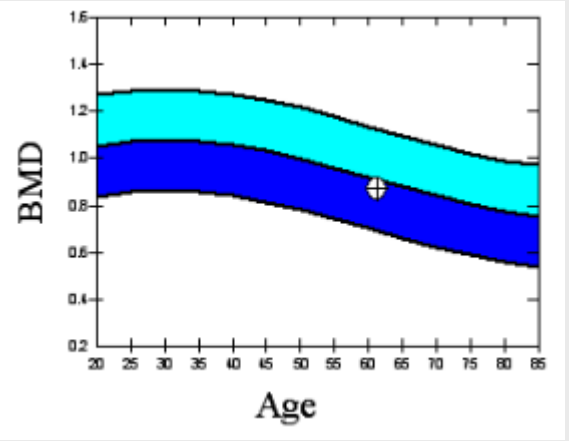


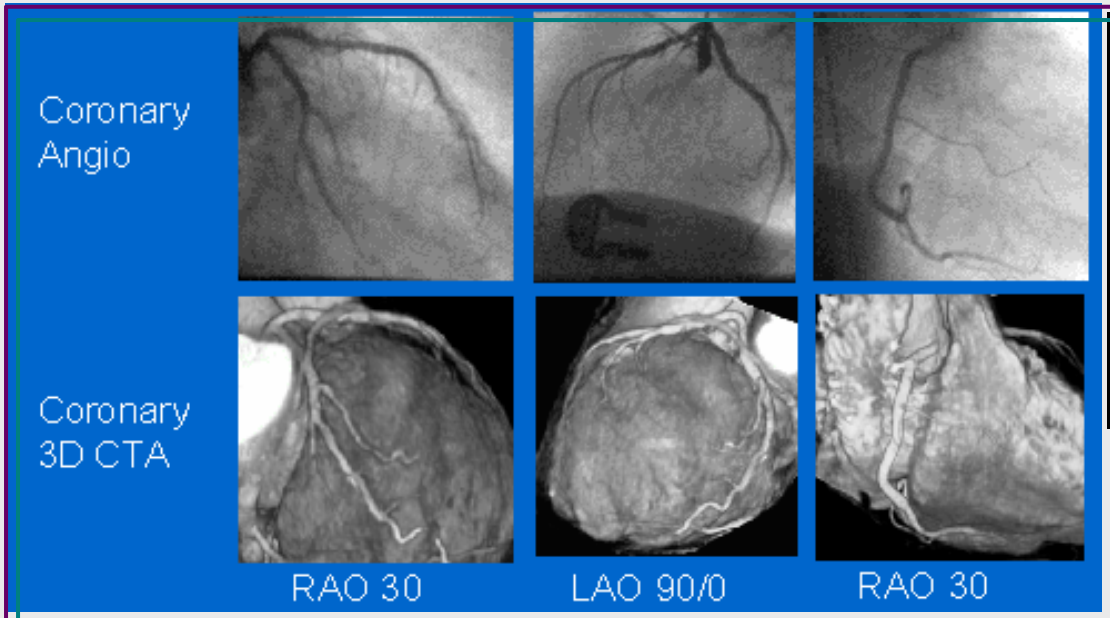




3D



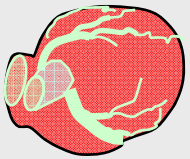


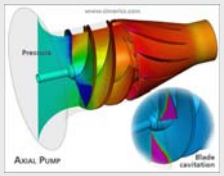


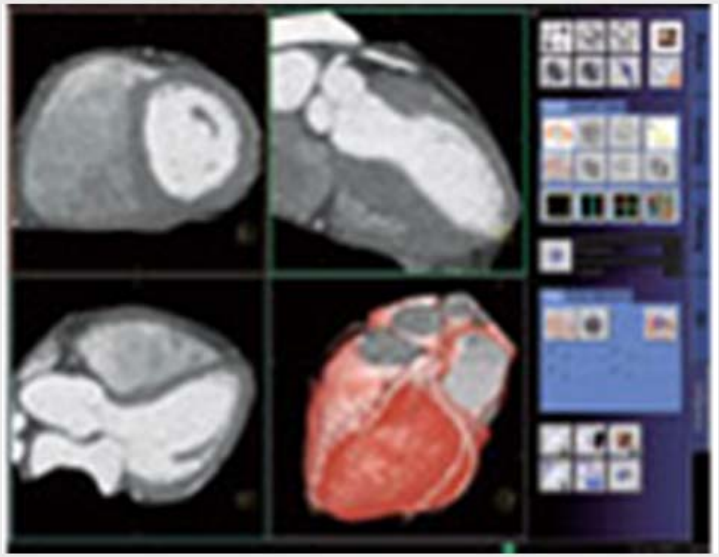
Cardiac Imaging

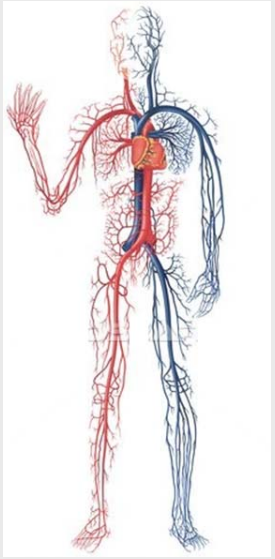
FUNCTION

- Atrial & Ventricular Volume
- Ejection Fraction
- Stroke Volume
- Cardiac Output
- Myocardial Perfusion
- Percent Stenosis
- Etc.



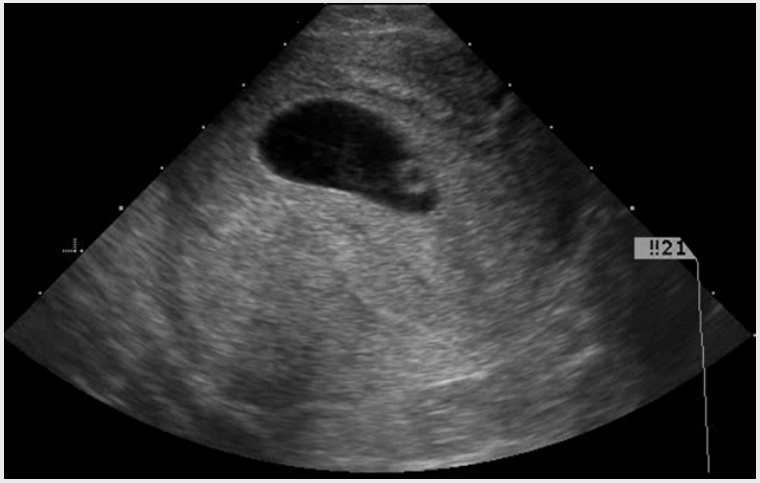


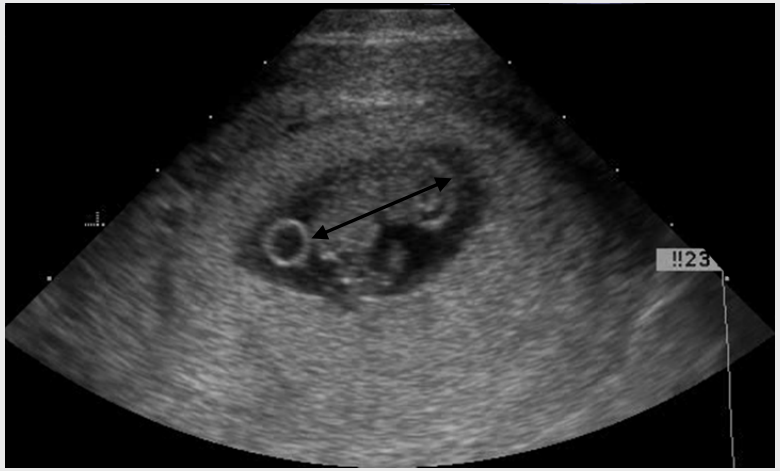


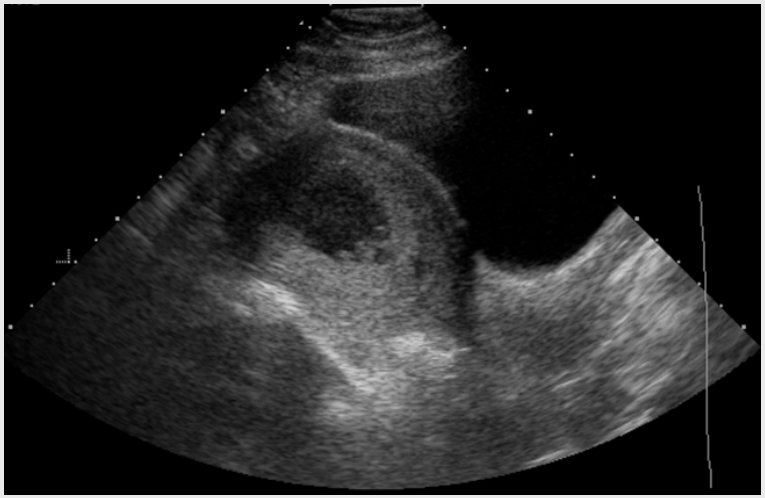


Crown Rump Length

AGE







FINDINGS:

Transabdominal and endovaginal pelvic ultrasound is reviewed with no comparisons. There is single live intrauterine gestation with fetal heart rate of 174 BPM. The gestational sac, amniotic sac, and yolk sac are unremarkable in morphology. Mean crown-rump length 22.5 mm, ultrasound MA 8 weeks, 6 days, ultrasound [redacted] This is concordant with given clinical EDD given in History.

Bilateral ovaries are identified endovaginally. The right ovary measures 2.1 x 2.8 x 1.5 cm, the left ovary measures 2.2 x 3.3 x 2.9 cm. No adnexal masses, no free fluid.

IMPRESSION:

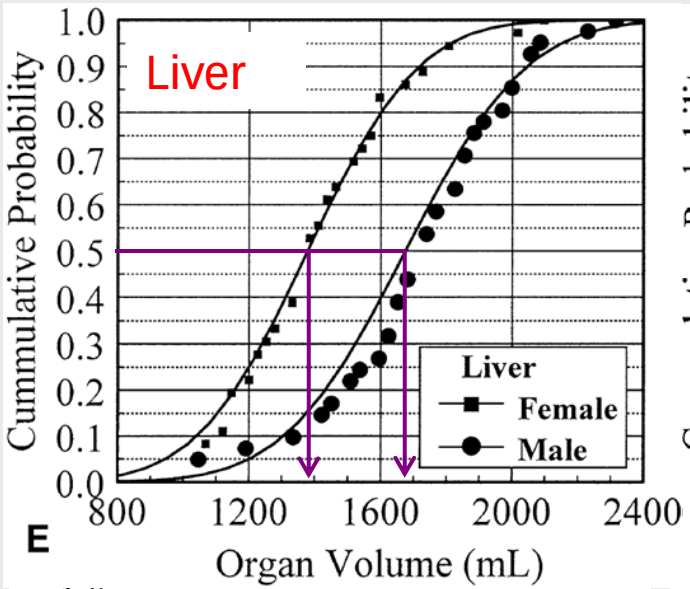
1. SINGLE LIVE INTRAUTERINE GESTATION WITH ULTRASOUND MA 8 WEEKS, 6 DAYS, AND ULTRASOUND [redacted]

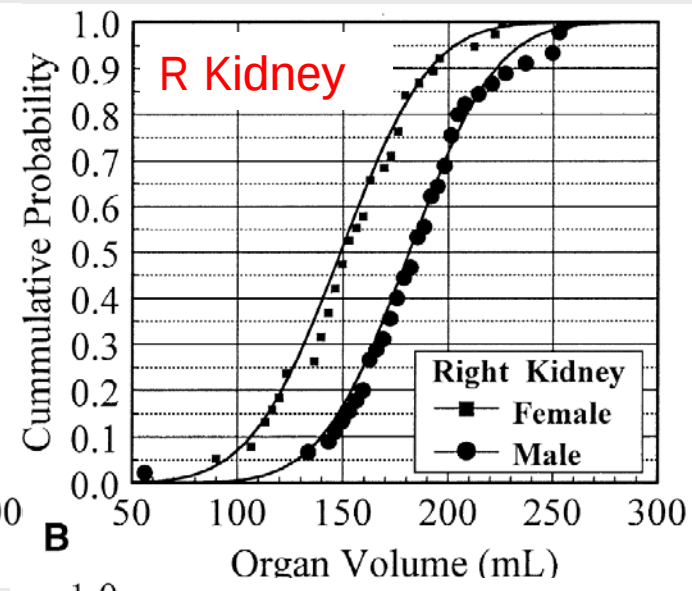
8 weeks 6 days

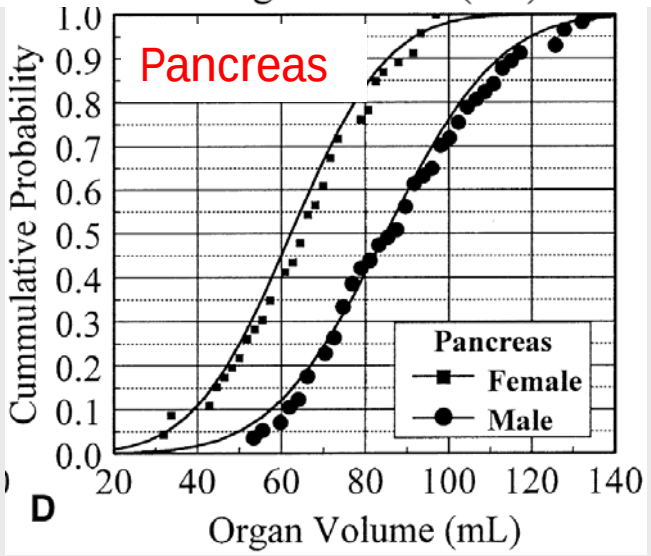
Normal organ volume assessment from abdominal CT

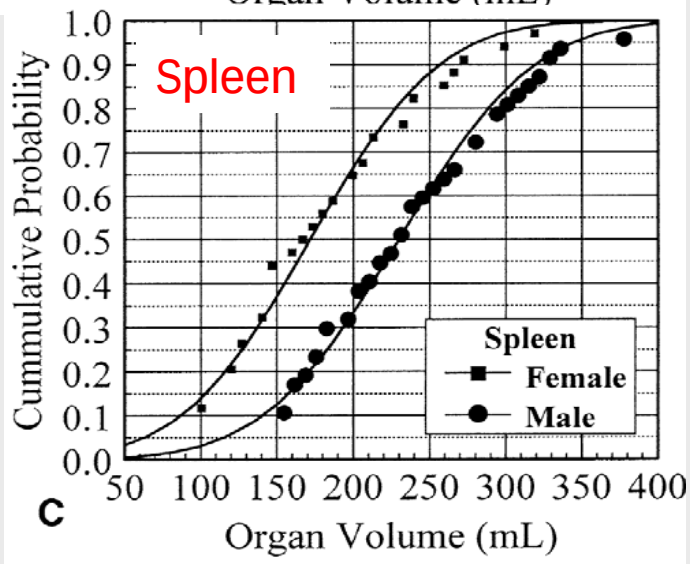
SIZE

E. M. Geraghty, J. M. Boone, J. P. McGahan, K. Jain

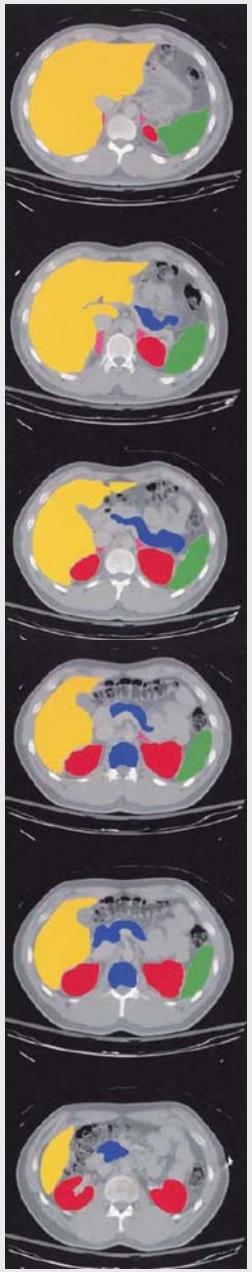








Journal of Abdominal Imaging **29**, 2004

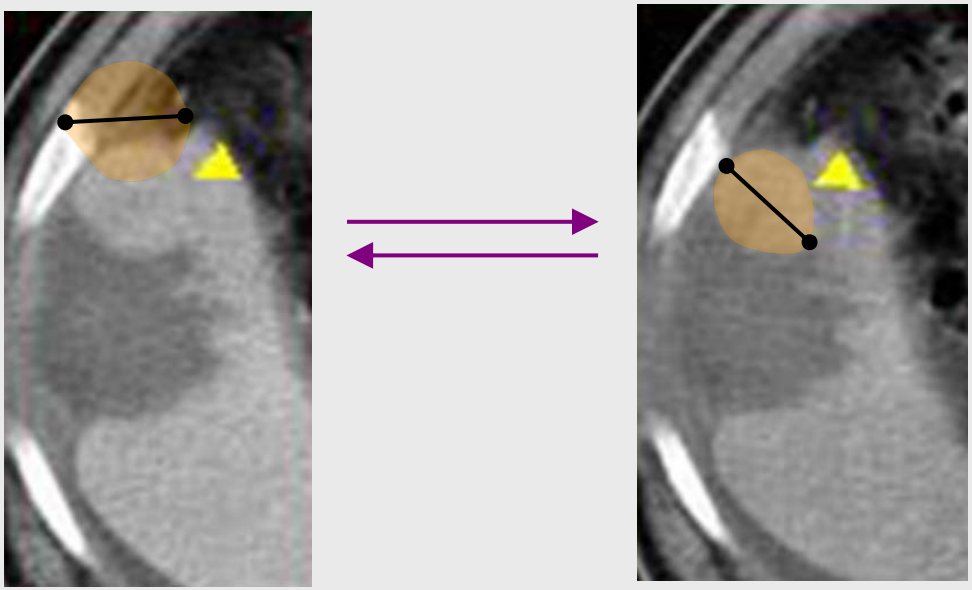


RESPONSE

RECIST

Response evaluation criteria in solid tumors

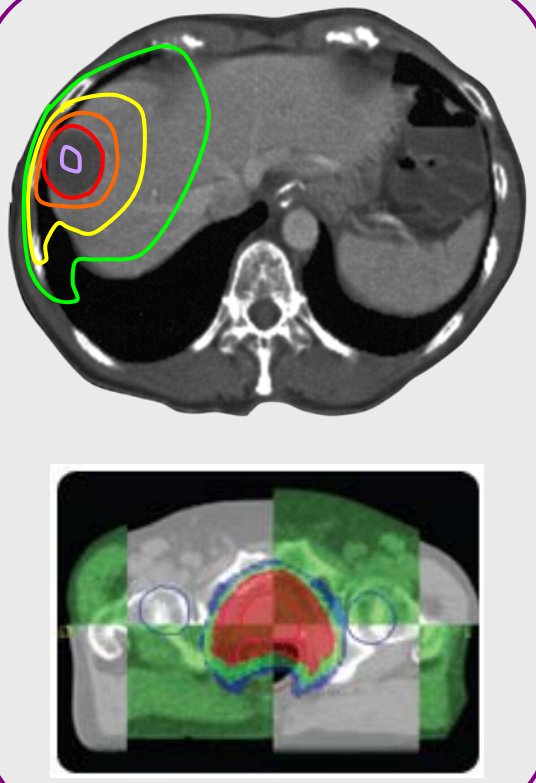
- Uni-dimensional measurement of tumor “size”
- Progression / Stable disease / Partial Response / Complete Response
- NIH-required imaging surrogate



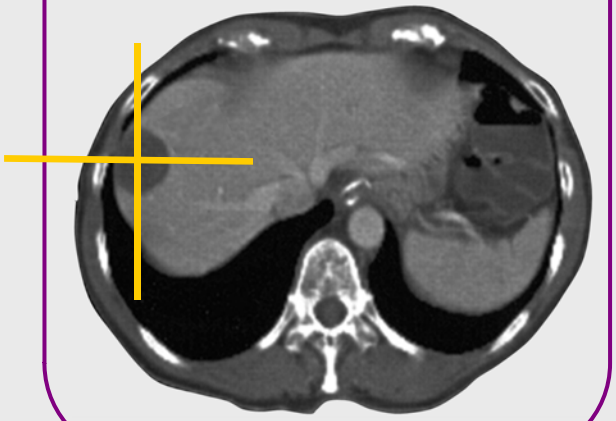
time 1

time 2

Radiation Therapy



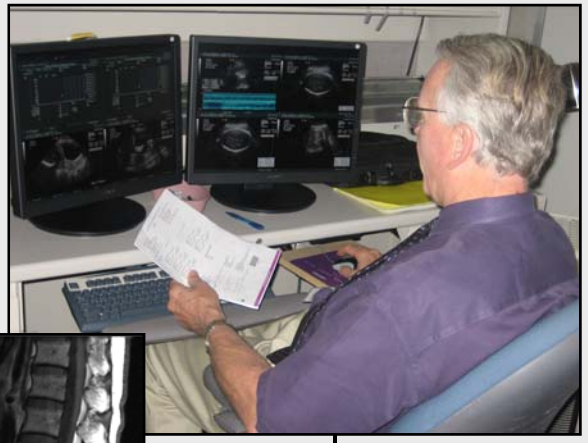
TREATMENT PLANNING

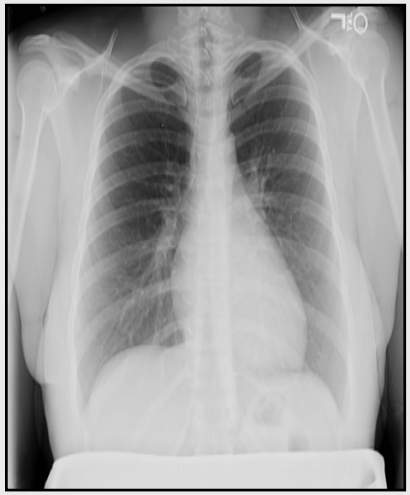


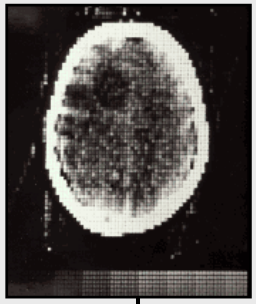
LOCALIZATION

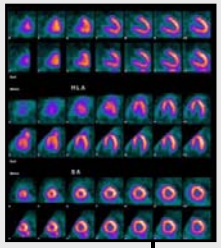
Future potential for Image-based Quantitative Metrics

The history of radiology:
Part 1: Past History









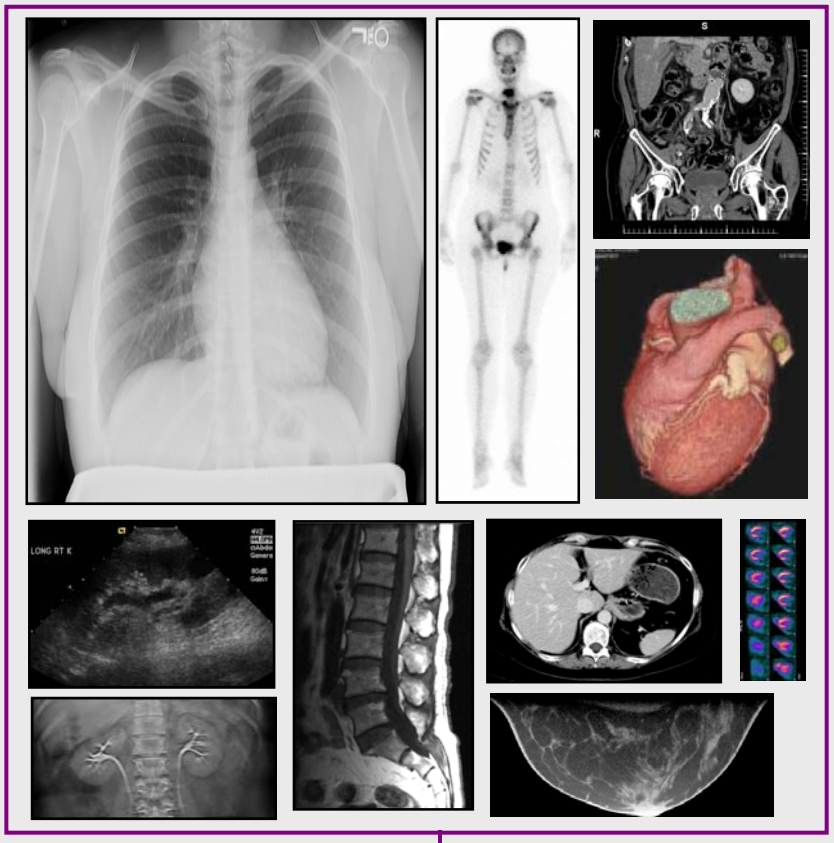
PACS

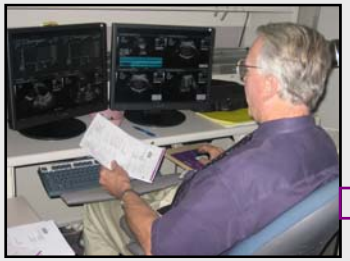
year 1943 1948 1958 1968 1978 1988 1998 2009

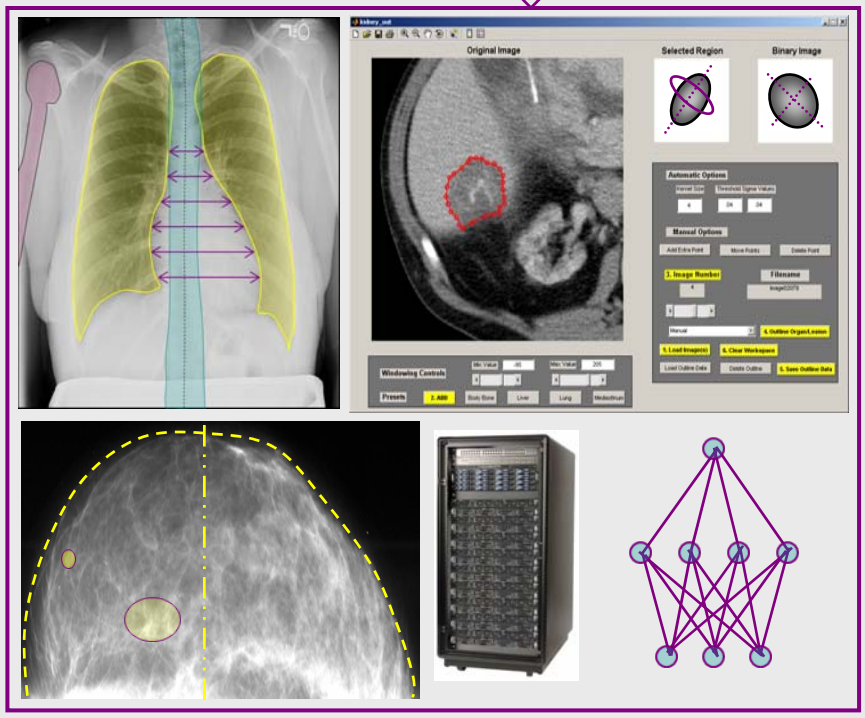
mostly analog mostly digital

The history of radiology:
Part 2: Future "History"

virtually all digital







Era of Quantitative Imaging

year 2009 2020 2040 2060 2080 2100 2109

mostly qualitative — mostly quantitative

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Science Council

Imaging Physics Committee (Shepard, Siewerdsen)

Therapy Physics Committee (Yorke, Huq)

Research Committee (Fraass, Fahrig)

Quantitative Imaging Initiative

TG: Quantitative PET/CT Imaging (Kinahan)

WG: Standards for Quantitative MR Measures (Jackson)

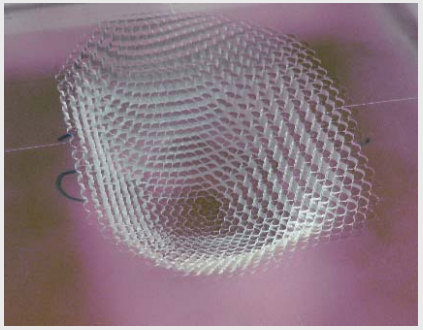
TG: Quantitative CT Imaging (Boone)

TG: Quantitative SPECT Imaging (Tsui)

AAPM FOREM

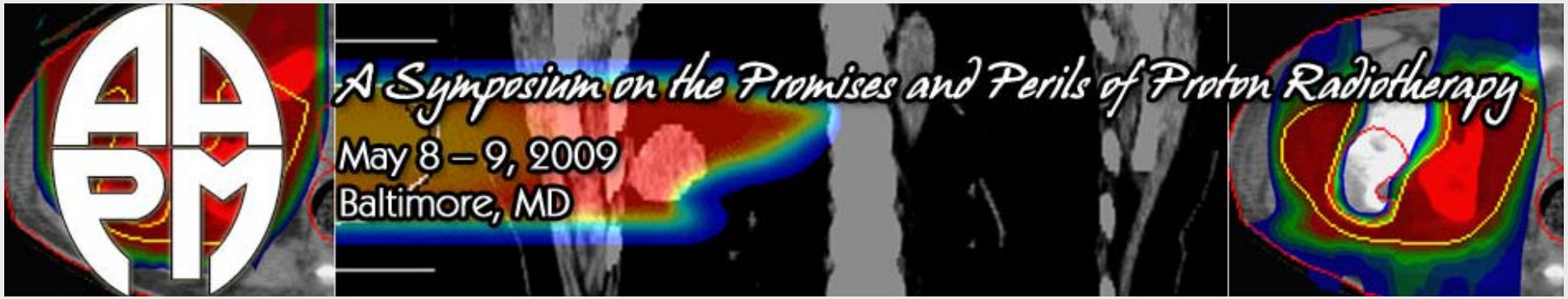
March 30-31, 2009 in Chicago, 20 participants

Model observers for tomosynthesis and CT of the breast: Theoretical and Practical considerations.



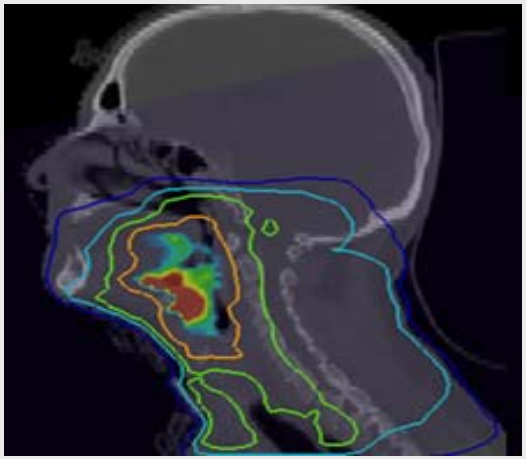
AAPM Proton Therapy Symposium

May 8-9, 2009 in Baltimore, ~200 participants



Imaging for Treatment Assessment in Radiation Therapy – iTART 2010

- **Imaging for target definition**
- **Imaging for treatment assessment**
- **Image quantification**
- **Industry, regulatory issues**



June 21-22, 2010
Lansdowne, VA

NIH grant submissions

- Calibration and validation in cancer imaging: The quantitative imaging initiative.

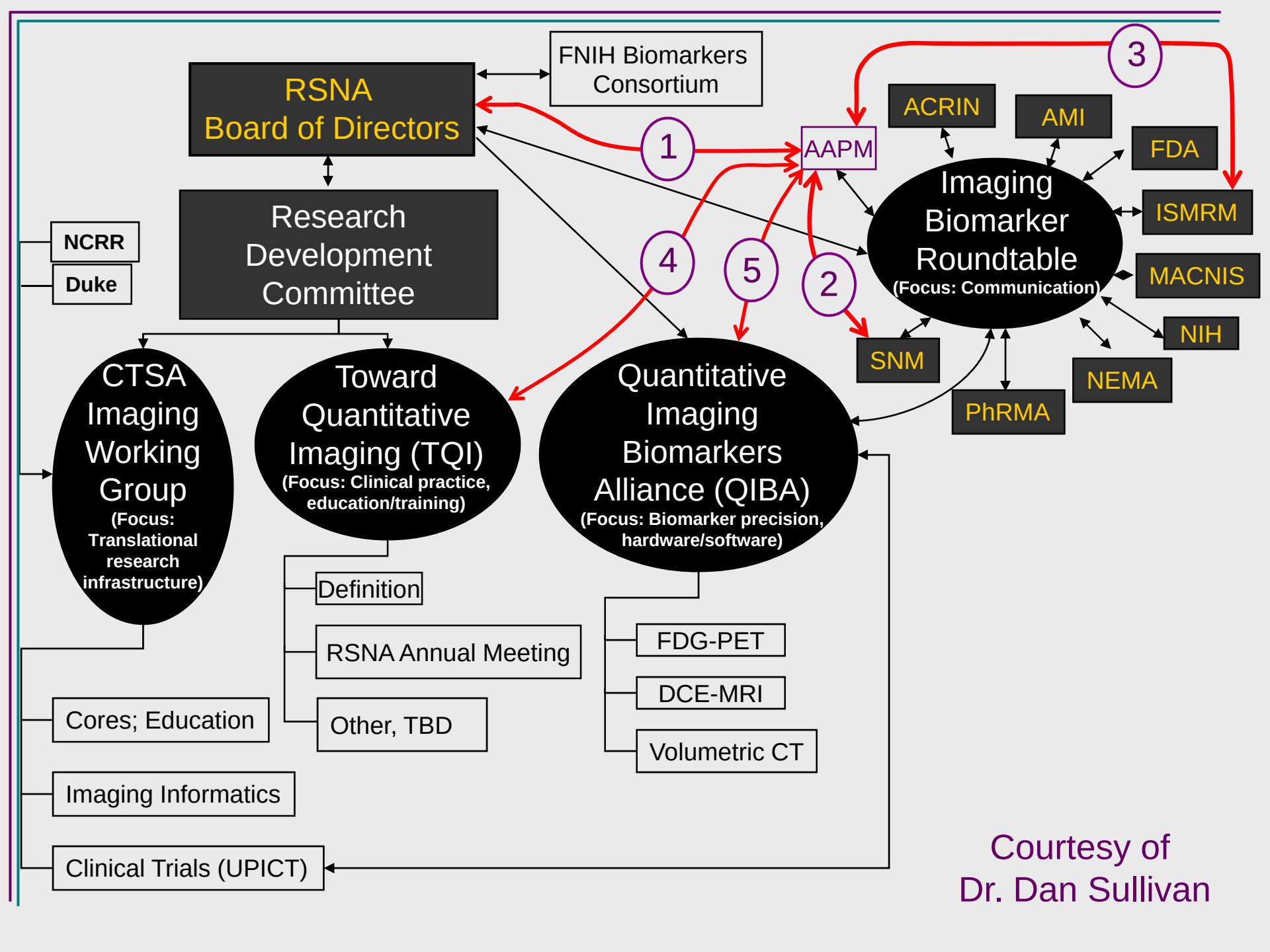
  J Boone, P Kinahan, E Jackson, B Tsui, ME Giger, etc.

  Specific Aims:
  PET/CT
  SPECT/CT
  CT
  MRI

- Technology assessment institute for medical imaging and image guided therapy.

  P Carson, W Hendee, E Samei, J Siewerdsen, etc.

  Specific Aims:
  Cone beam CT
  Dose reduction in pediatric CT
  Breast tomosynthesis
  Ultrasound Contrast agent



Courtesy of
Dr. Dan Sullivan

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Anaheim in 2009

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Hello Dr. Boone...

What's New

2009 Amendments to AAPM Governance Documents [general | posted: 6/24/2009 | sunset: 7/31/2009]

New York Times reports 'Rogue Cancer Unit' at Philadelphia VA Hospital [general | posted: 6/23/2009 | sunset: 7/23/2009]

Canada approves new source of medical isotopes [general | posted: 6/17/2009 | sunset: 7/17/2009]

2008 Education & Research Fund Annual Report [general | posted: 6/16/2009 | sunset: 7/16/2009]

Website Editor Report, June 2009 [general | posted: 6/1/2009 | sunset: 7/15/2009]

2009 AAPM Annual Meeting - Meeting Program Available [meetings | posted: 5/14/2009 | sunset: 7/30/2009]

RSNA 2009 - Registration and Housing Open for AAPM and RSNA Members [general | posted: 4/29/2009 | sunset: 11/6/2009]

Awards & Honors Committee - Call for Nominations [general | posted: 4/27/2009 | sunset: 10/15/2009]

Awards & Honors Committee - Call for Competitive Applications for Travel Grants [general | posted: 4/27/2009 | sunset: 10/15/2009]

2009 Dues Paid - choose to pay for other options. [membership]

focus on our future

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AAPM BBS
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Current Issues

Recent Quizzes in Continuing Education
» 1/5/2009 9:53:10 AM: Robot-assisted & 3D ultrasound-guided prostate brachytherapy
» 1/5/2009 9:53:09 AM: Understanding and Teaching Ultrasound Physics

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Specific methods in QI for Image Calibration

Phantom Fabrication

Phantom Image Analysis

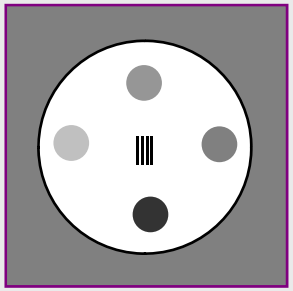
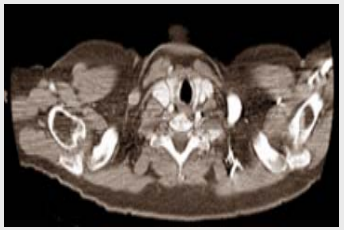
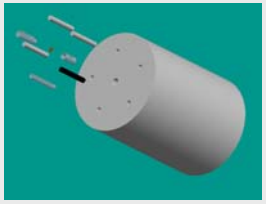
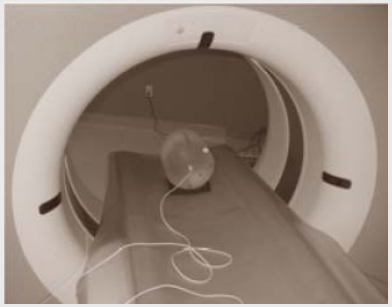


Image Calibration

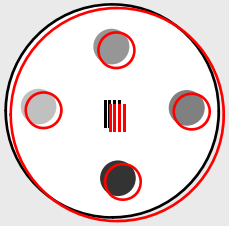




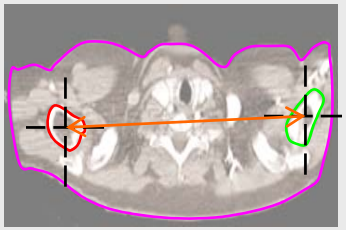
Phantom Design



Phantom Imaging



Correction Techniques



Independent Validation

Quantitative Parameters of Interest

Spatial integrity ([x,y,z] → distance, area, volume)

Gray scale (HU) calibration

Flow rate accuracy

Temporal accuracy

Physiologic/anatomic parameters

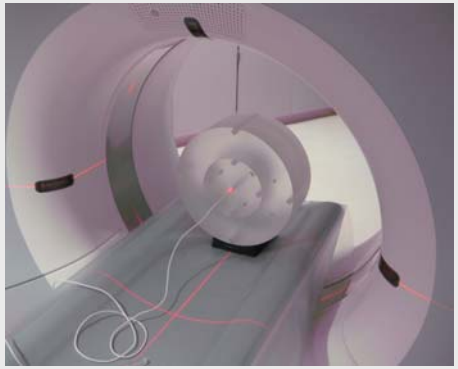
Volume change, Uptake, flow, perfusion, kinetic assessment, permeability. others....

Precision over time with same scanner

Precision between different scanners

General themes in QI for imaging systems

Scanner Calibration

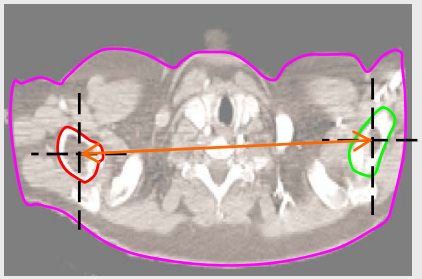


Protocol Development

1. Do this do that
2. Do that then this
3. Don't do that
4. Do this and that
5. Wait for a while
6. Weigh patient
7. Perform patient survey
8. Bundle images
9. Recruit readers
10. Patient follow-up

Implementation

Demonstration of QI utility



Variance Reduction

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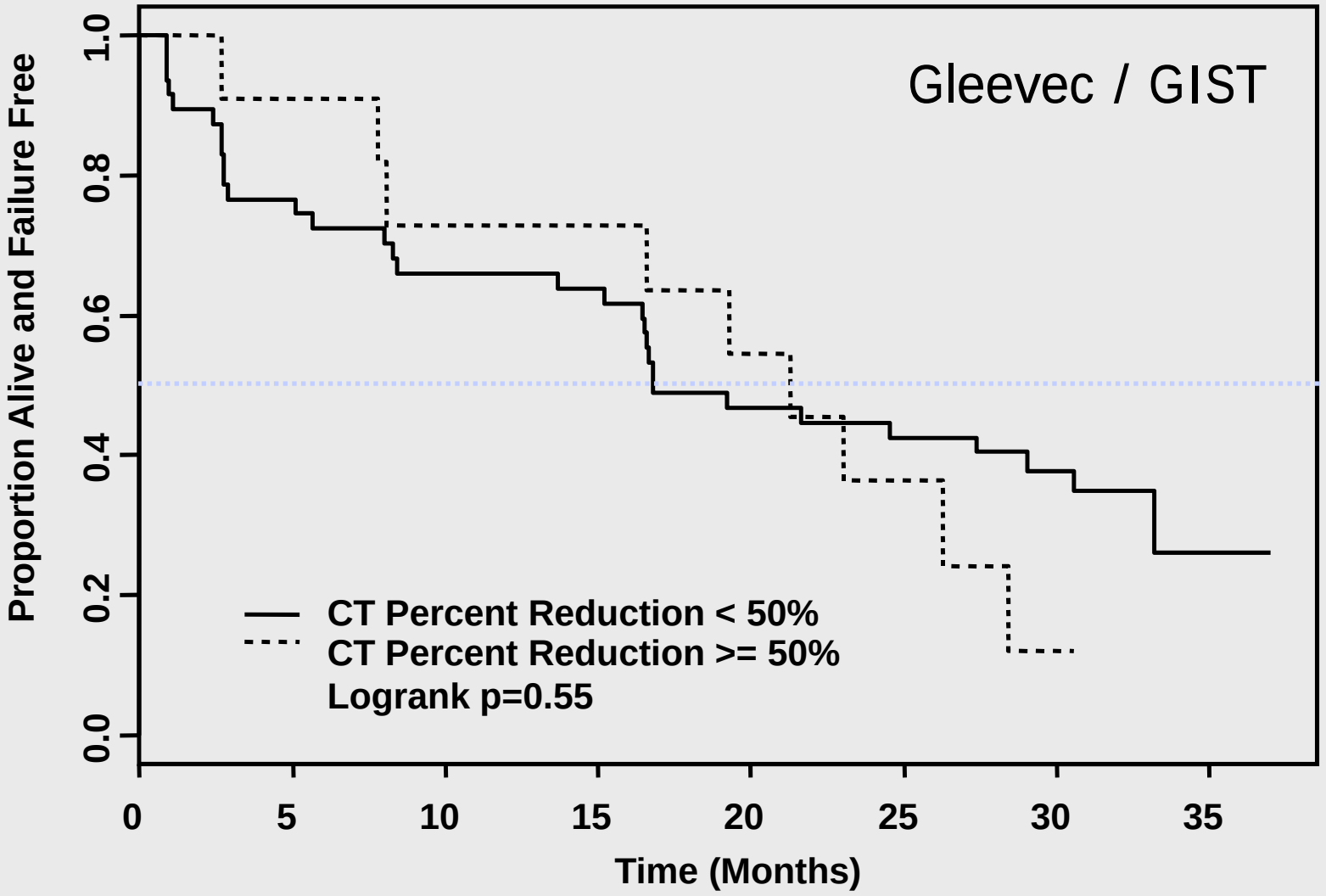
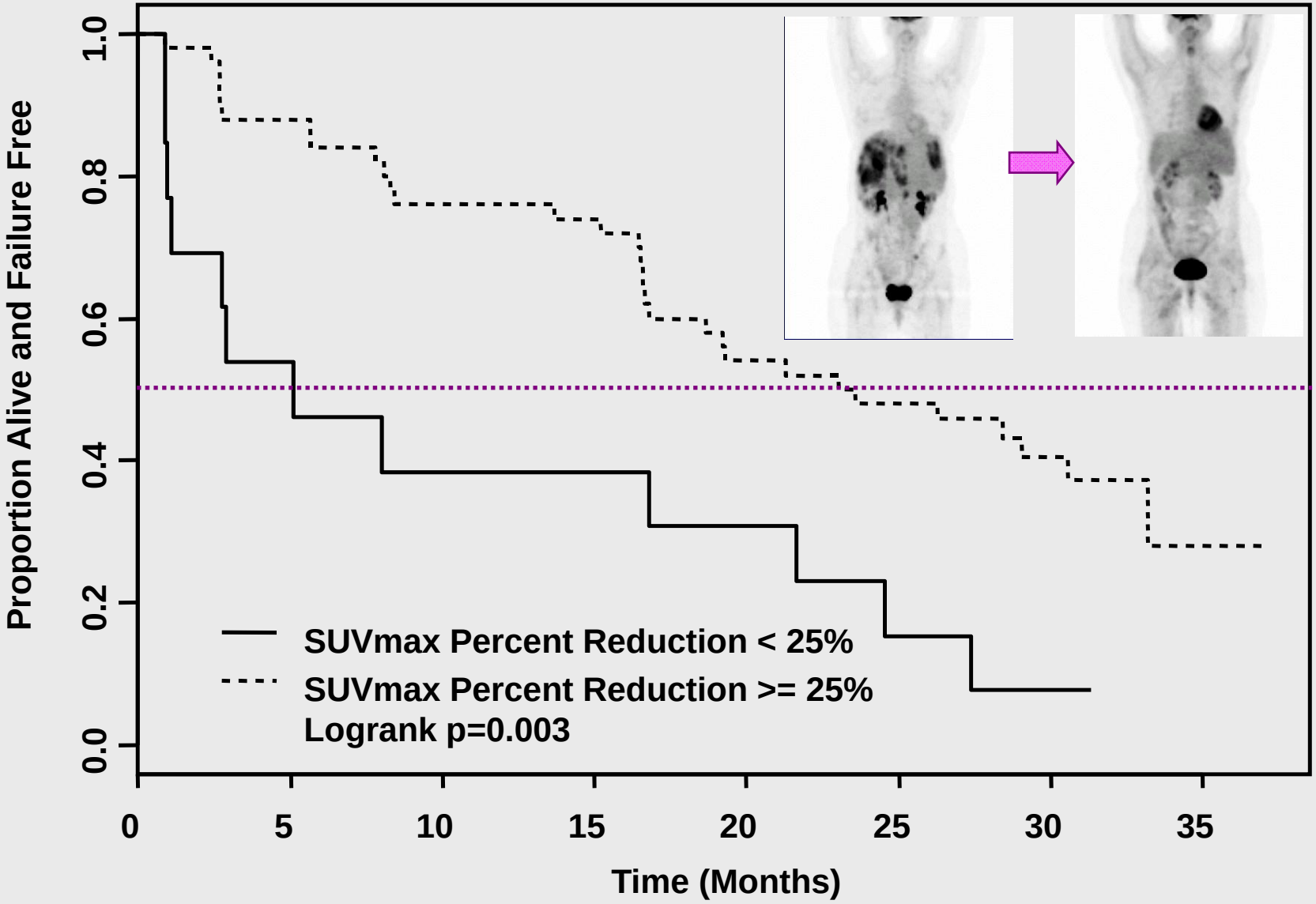
Time to Treatment Failure by Percent CT Reduction Days 21-40



Holdsworth, et al - Dana-Farber Cancer Institute

Time to Treatment Failure by SUV_{max} Percent Reduction



Van den Abbeele, et al - Dana-Farber Cancer Institute

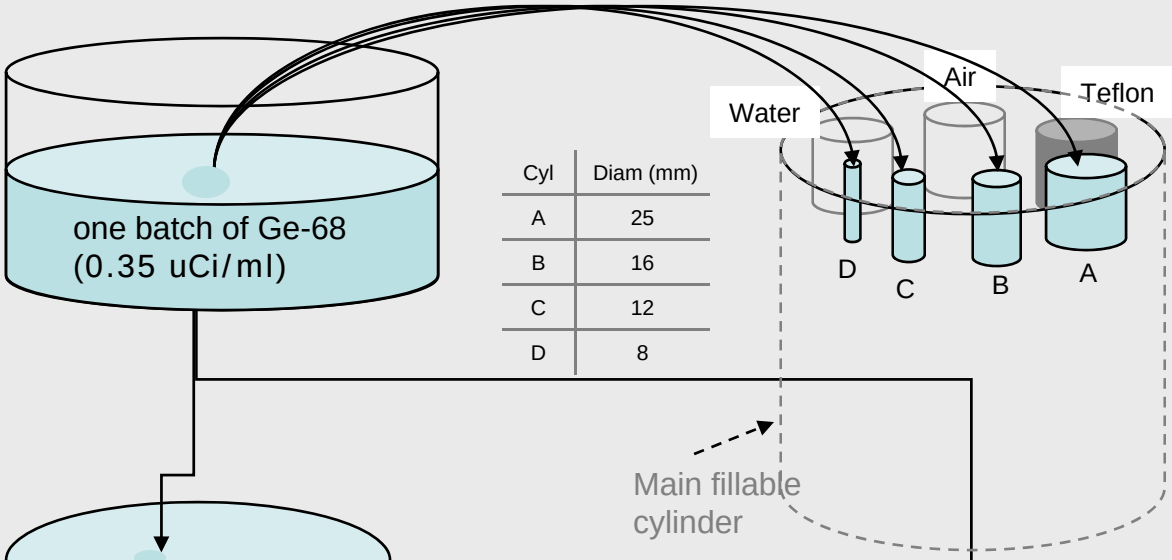
Quantitative Imaging Using PET/CT

Paul Kinahan, PhD

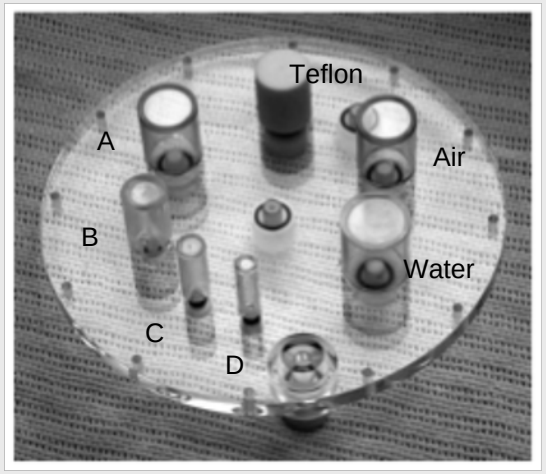
Director of PET/CT Physics
Imaging Research Laboratory, Department of Radiology
University of Washington, Seattle, WA

SNM Clinical Trials Network Community Workshop
February 8-9, 2009
Clearwater, FL

AAPM / SNM Task Group 145: Modified ACR Phantom



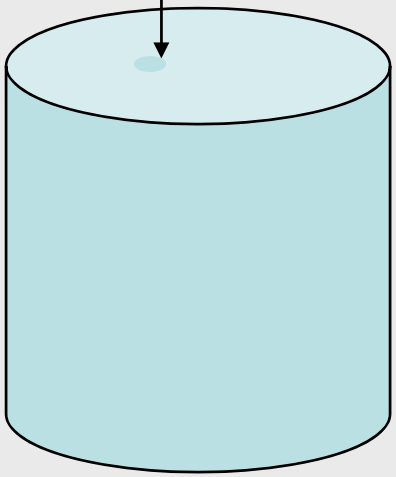
Cyl	Diam (mm)
A	25
B	16
C	12
D	8



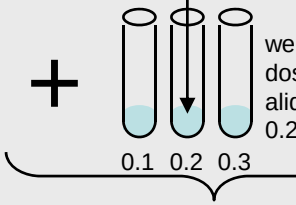
ACR phantom lid

Image with FDG in main cylinder

ACR phantom w/ extra lid with Ge-68 activity in cylinders A-D only



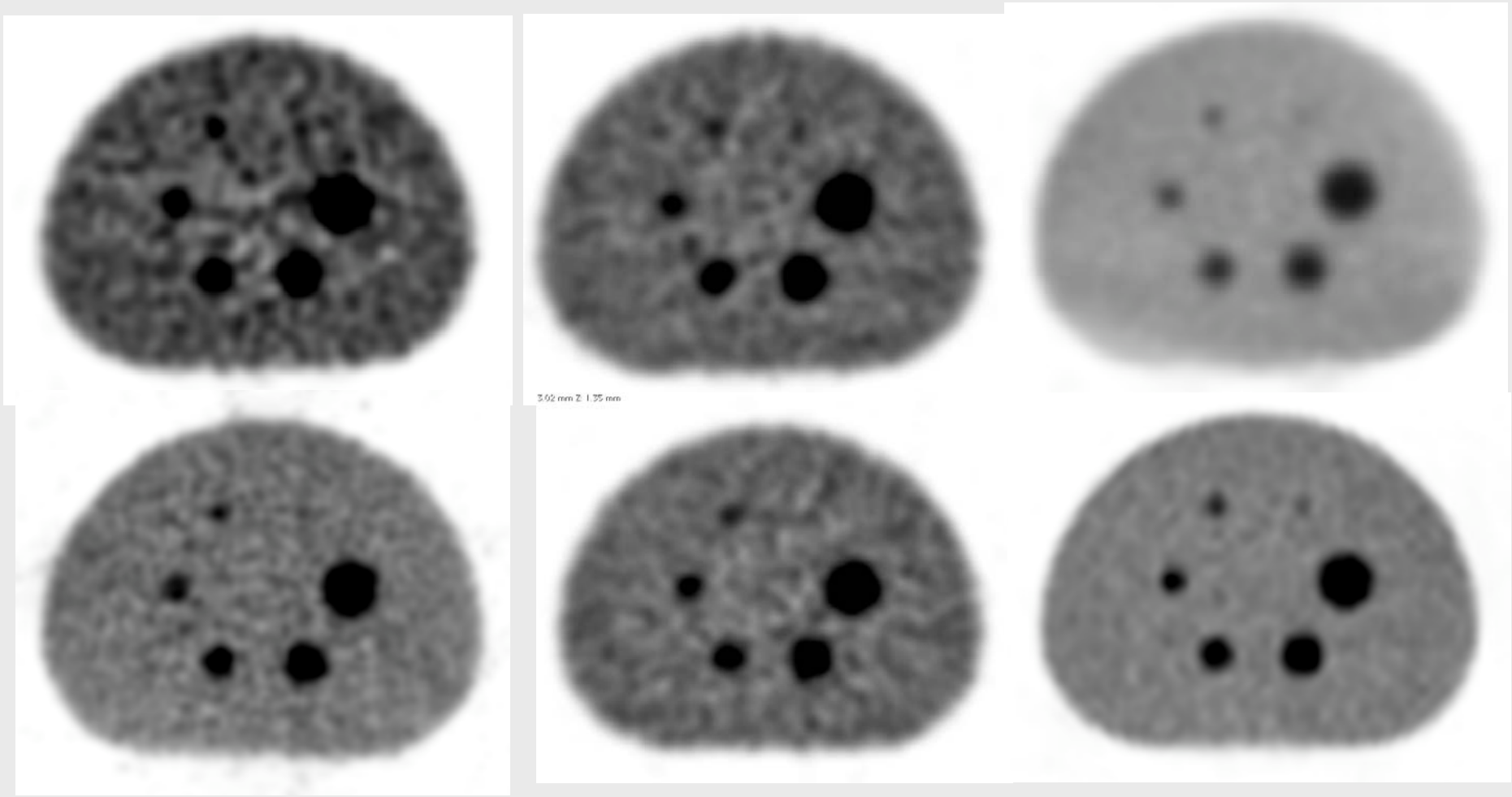
Reference standard 20 cm uniform cylinder (one only)
2 mCi total activity



Shipping case with:
- empty ACR phantom
- matched lid with Ge-68 in cylinders A-D
- one each of aliquots of 0.1, 0.2, 0.3 ml
- Total activity 12 uCi

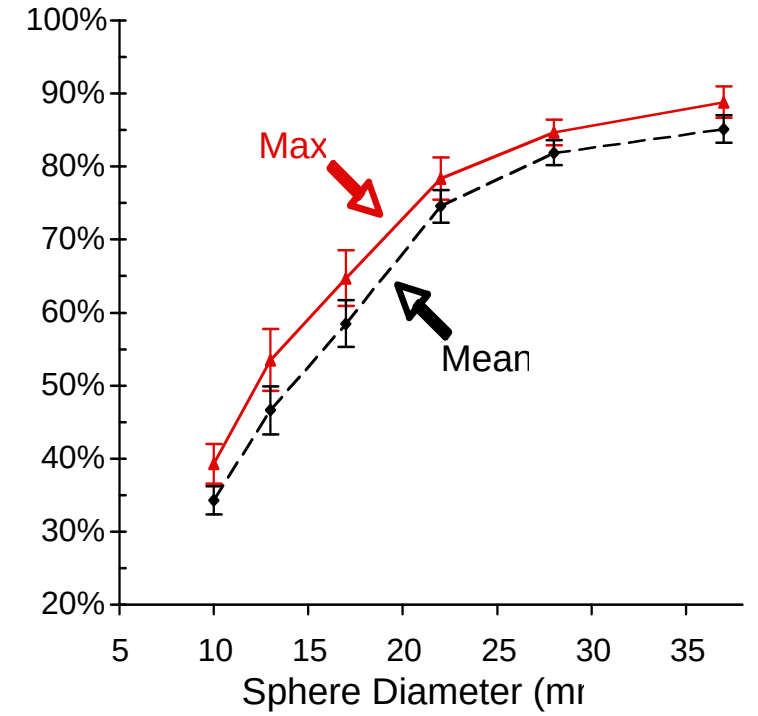
X 3

Sample Image Sections from Six Different Scanners

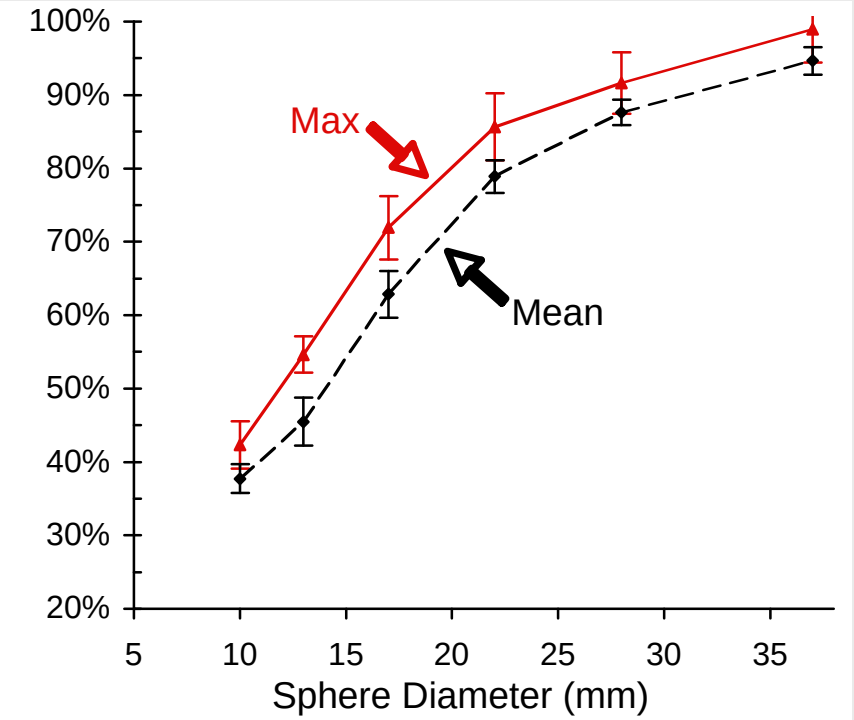


‘Coffee Break’ Repeat PET/CT scans with Repositioning

SUVs from 20 3D-OSEM scans with 7-mm smoothing



GE DSTE-16 PET/CT Scanner



Siemens Biograph HI-REZ-16 PET/CT Scanner

- Intra-scanner short-term variability is 3% - 4%

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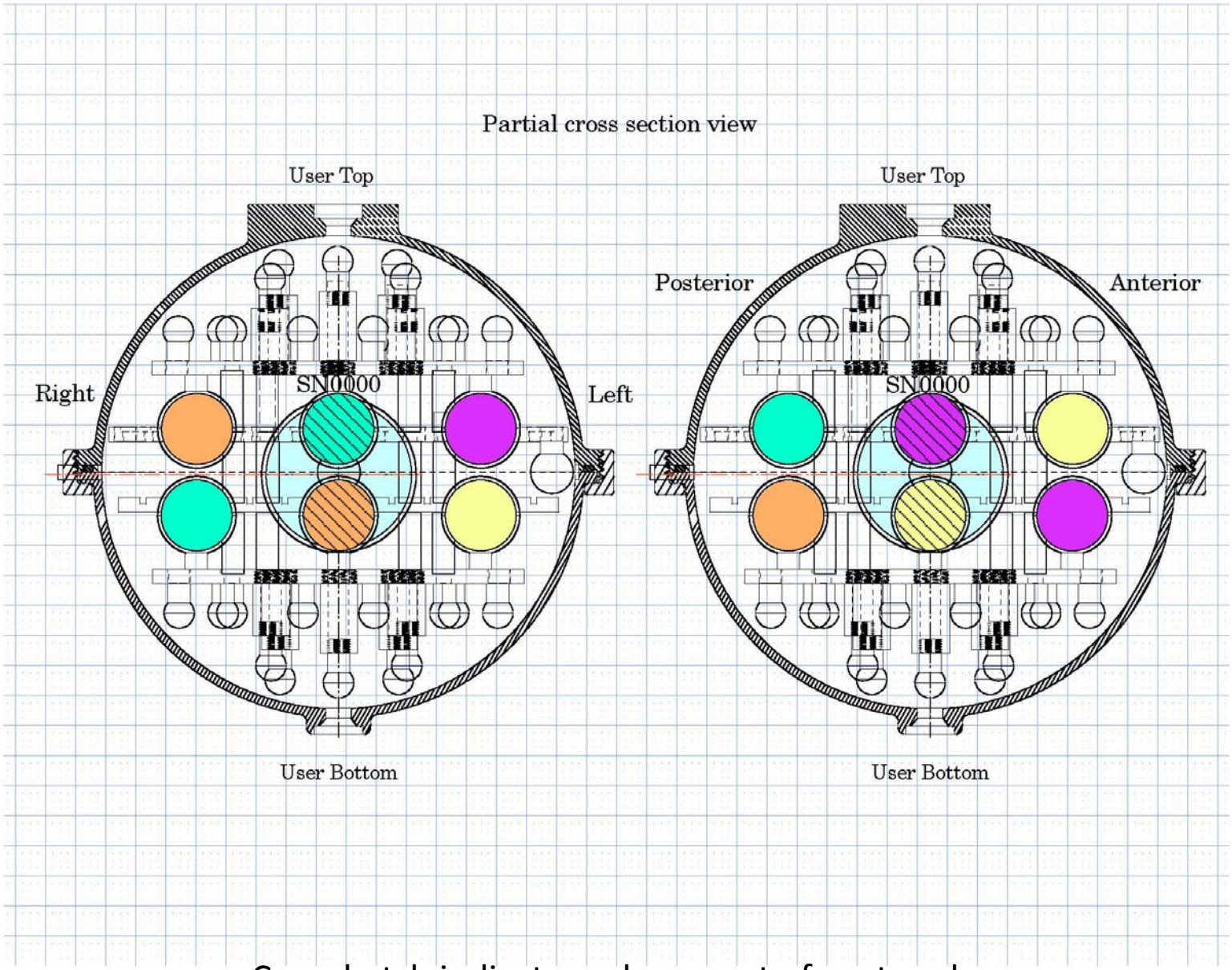
Sketches of DCE-MRI phantom

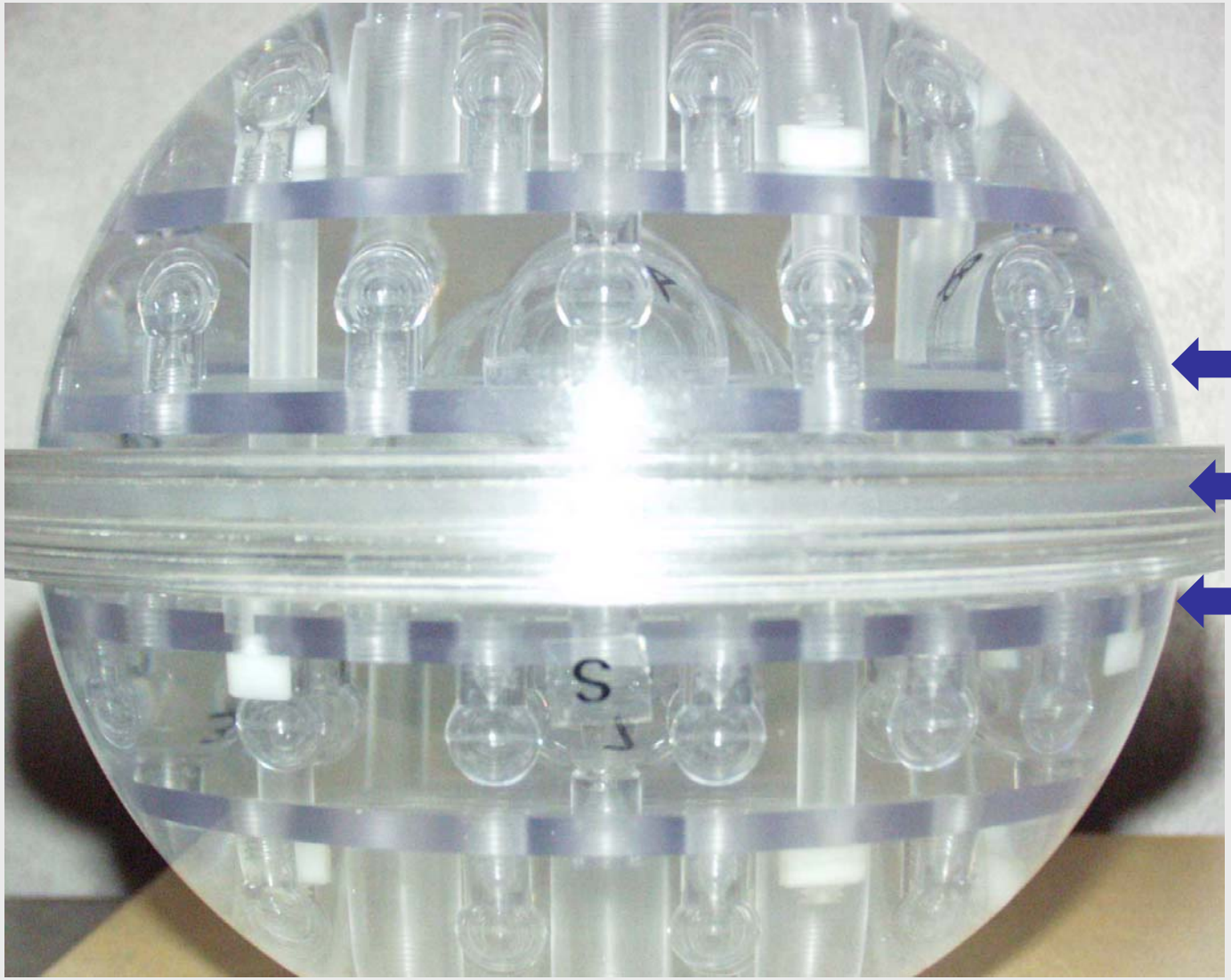


Cross hatch indicates spheres out of center plane

M. H. Buonocore, IRAT MRI Subcommittee
Joshua Levy, Phantom Laboratory

Locations of Posterior, Middle and Anterior slices

Anterior

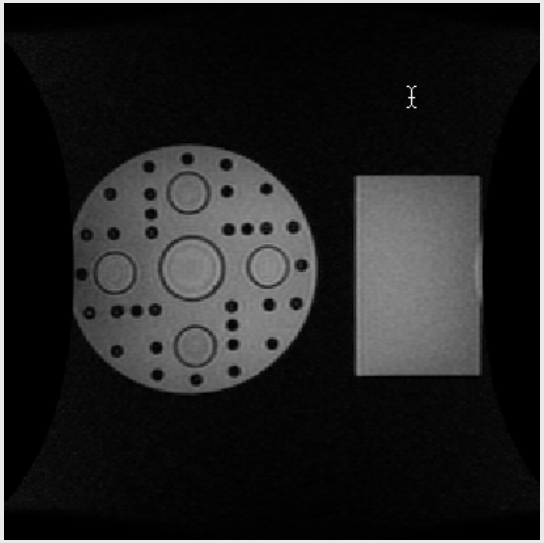


Posterior

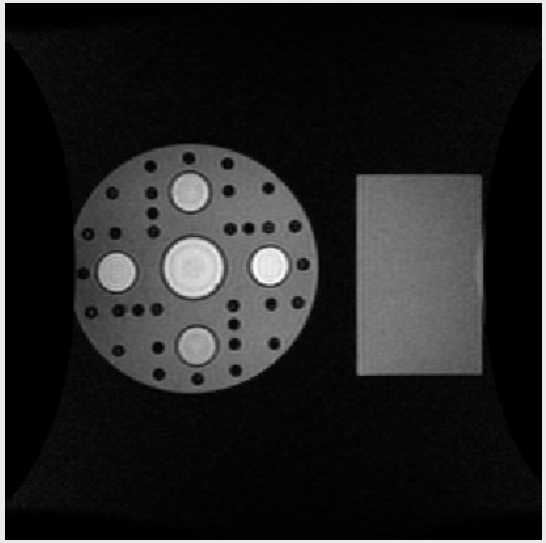
M. Buonocore, IRAT MRI Subcommittee

Figure A.13, Figure A.14

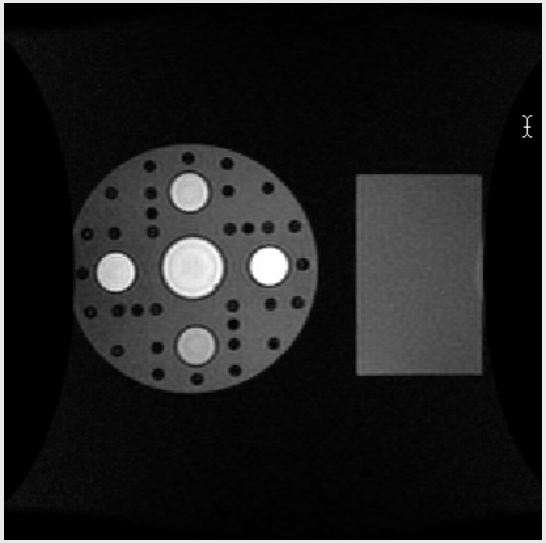
FSPGR (Anterior slice, Position-S)



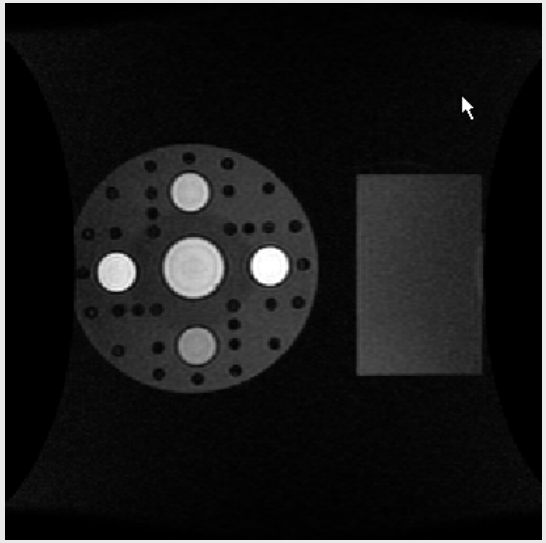
3°



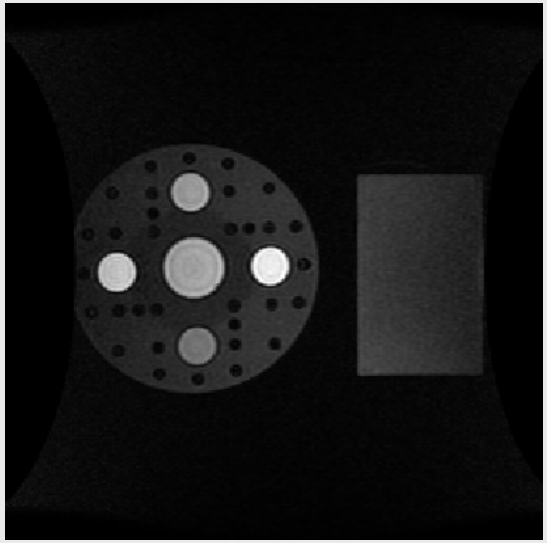
6°



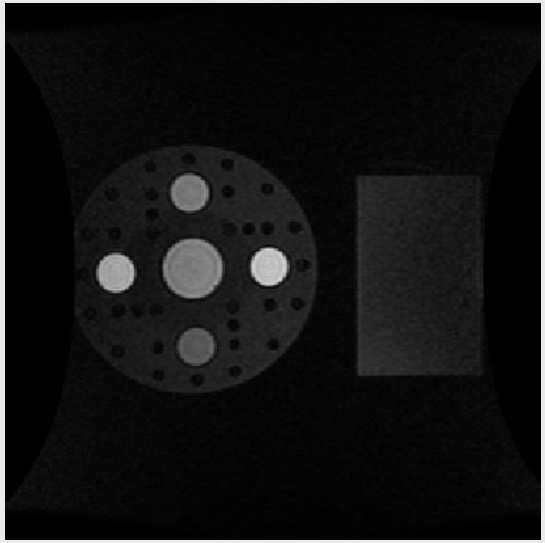
9°



15°



24°



35°

M. Buonocore, IRAT MRI Subcommittee

T1 values (Posterior slice)

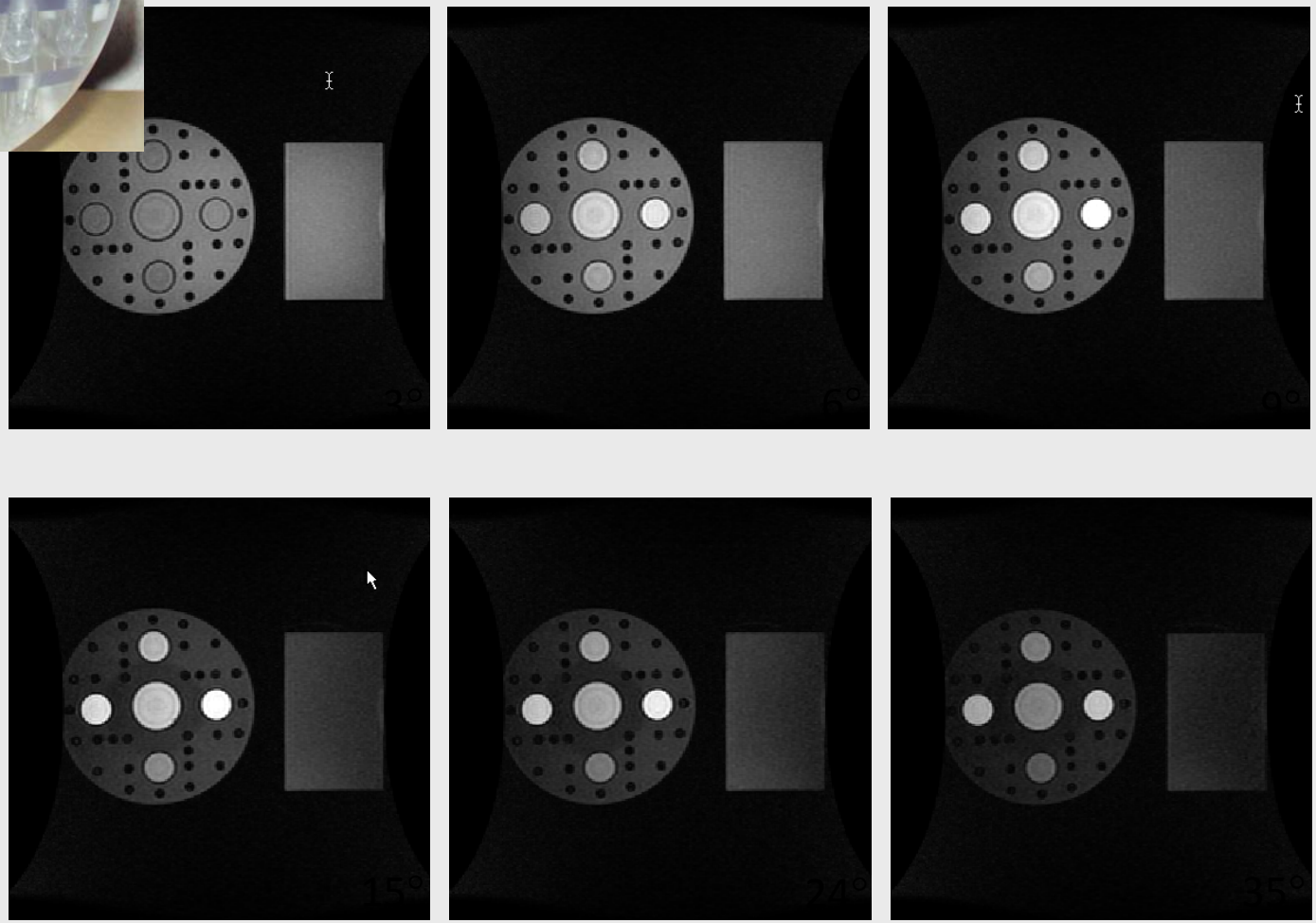
	Top	Left	Bottom	Right	Middle
"S"	237.8	783.9	310.8	480.2	411.6
"R"	468.4	252.2	728.5	331.8	413.5
"I"	326.2	489.1	237.0	769.5	419.9
"L"	719.3	335.9	439.1	240.0	401.1
Ave ("S")	**241.8**	**750.3**	**326.2**	**469.2**	**411.5**
Expected	*295.0*	*804.5*	*385.7*	*532.2*	*417.5*

T1 values (Anterior slice)

	Top	Left	Bottom	Right	Middle
"S"	354.5	215.2	537.6	275.1	412.4
"R"	261.2	371.8	201.3	563.9	401.1
"I"	540.5	276.5	368.9	214.7	407.4
"L"	205.7	579.4	275.3	386.0	416.4
Ave ("S")	**370.3**	**209.2**	**555.4**	**272.0**	**409.3**
Expected	*449.4*	*260.0*	*644.3*	*335.1*	*417.5*

Variability between scanners

use of calibration methods (phantoms and software) across
scanner platforms and acquisition techniques.



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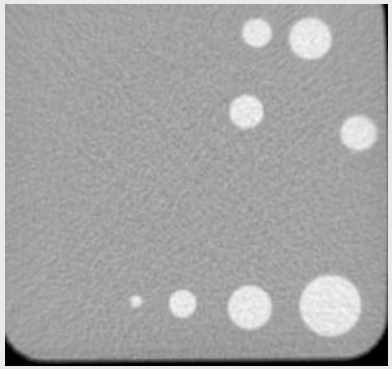
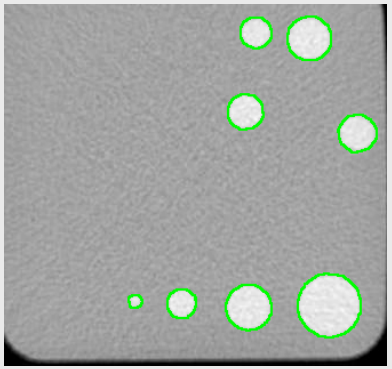
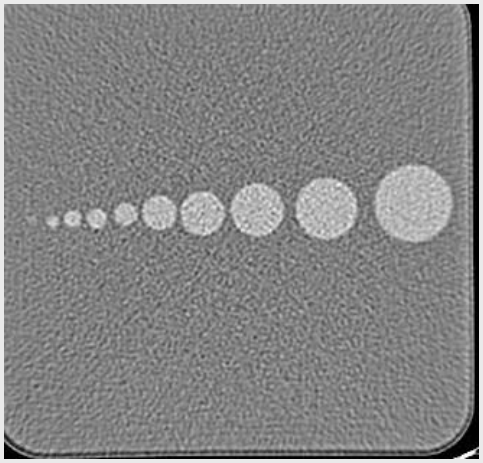
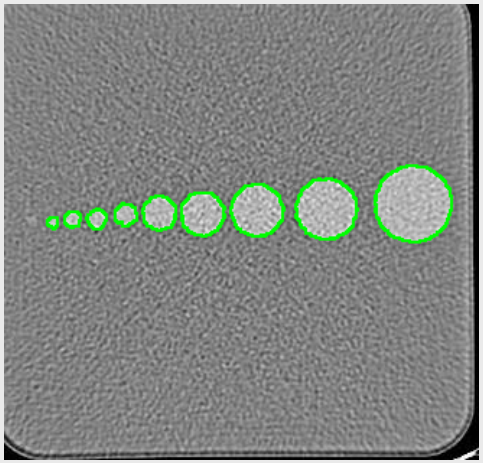
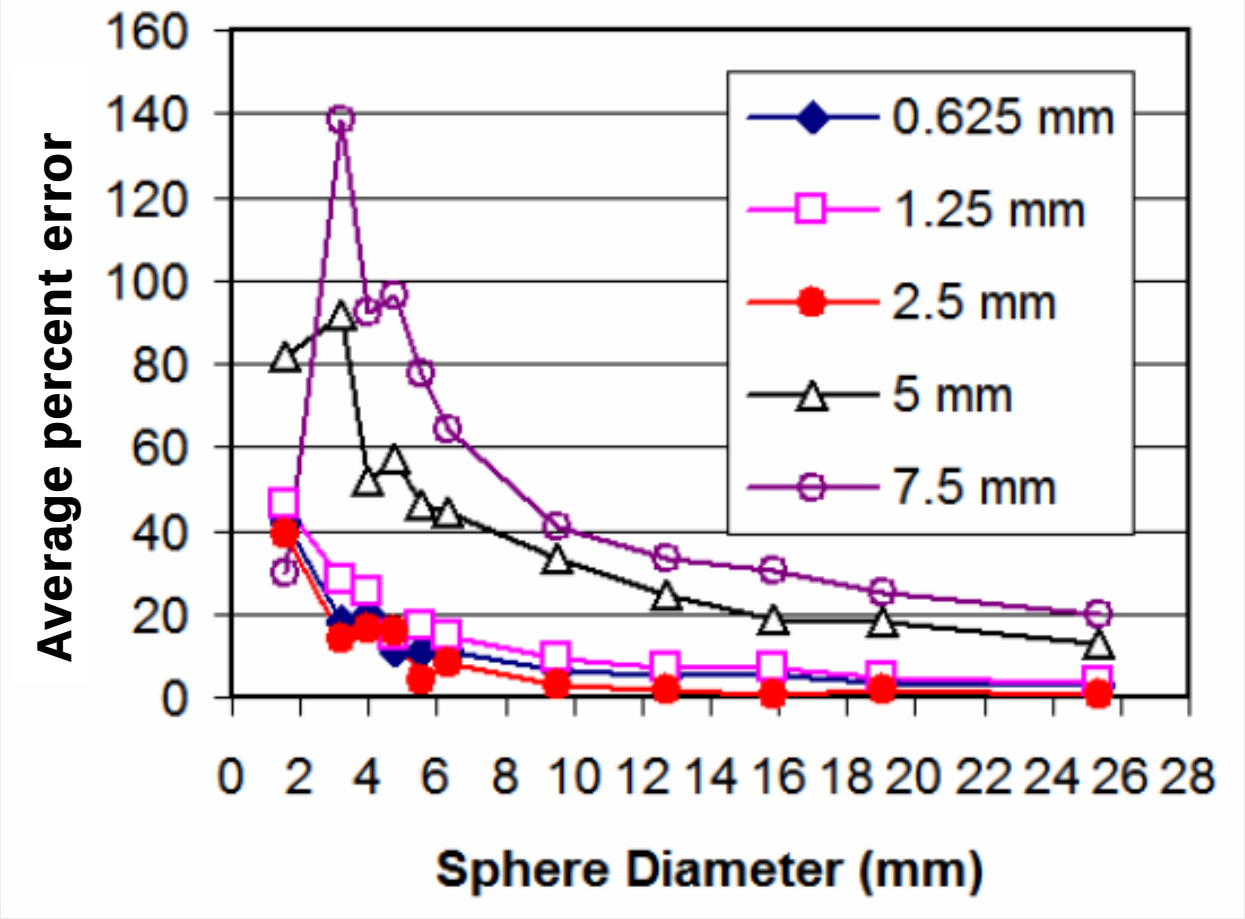
CT volume accuracy

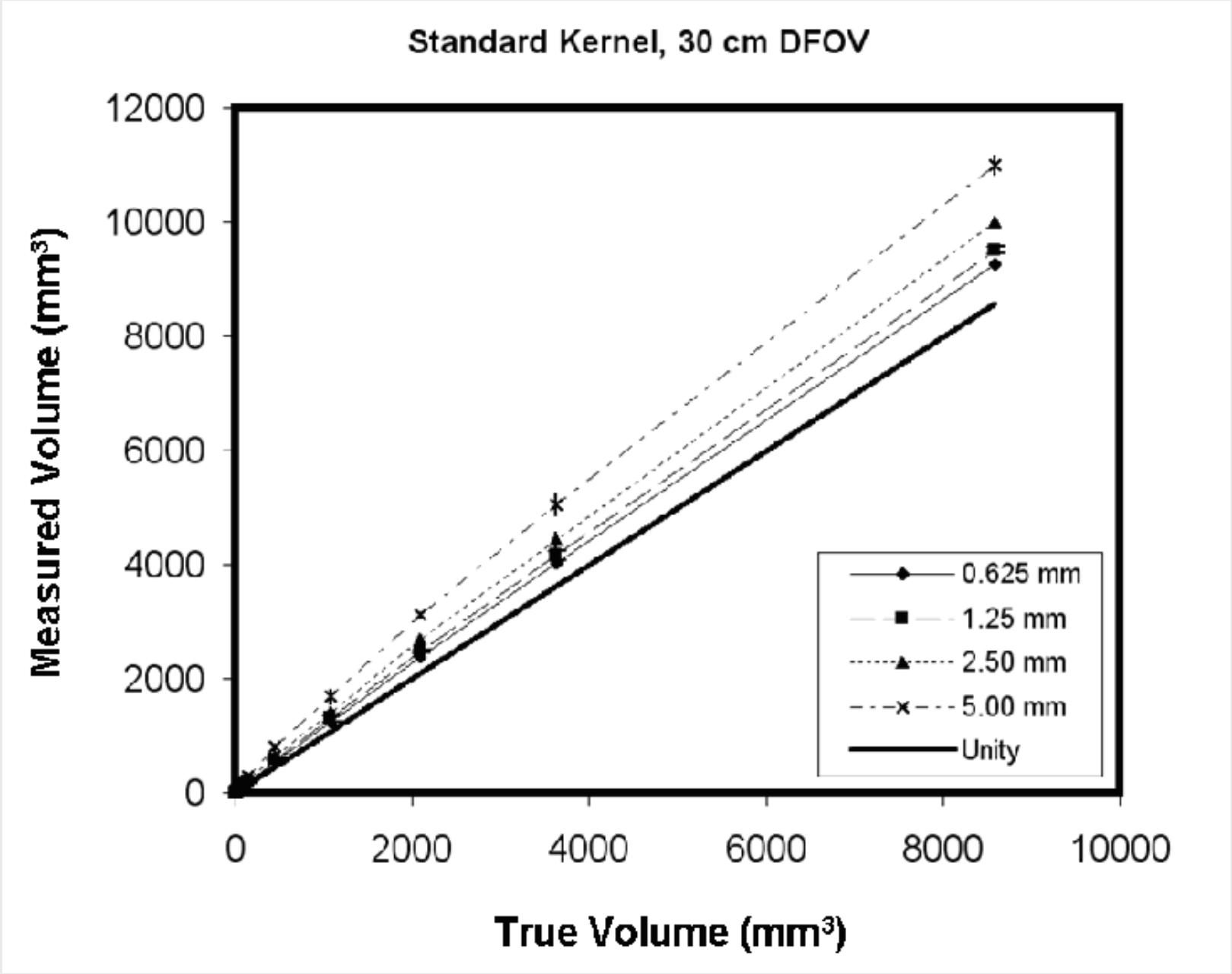


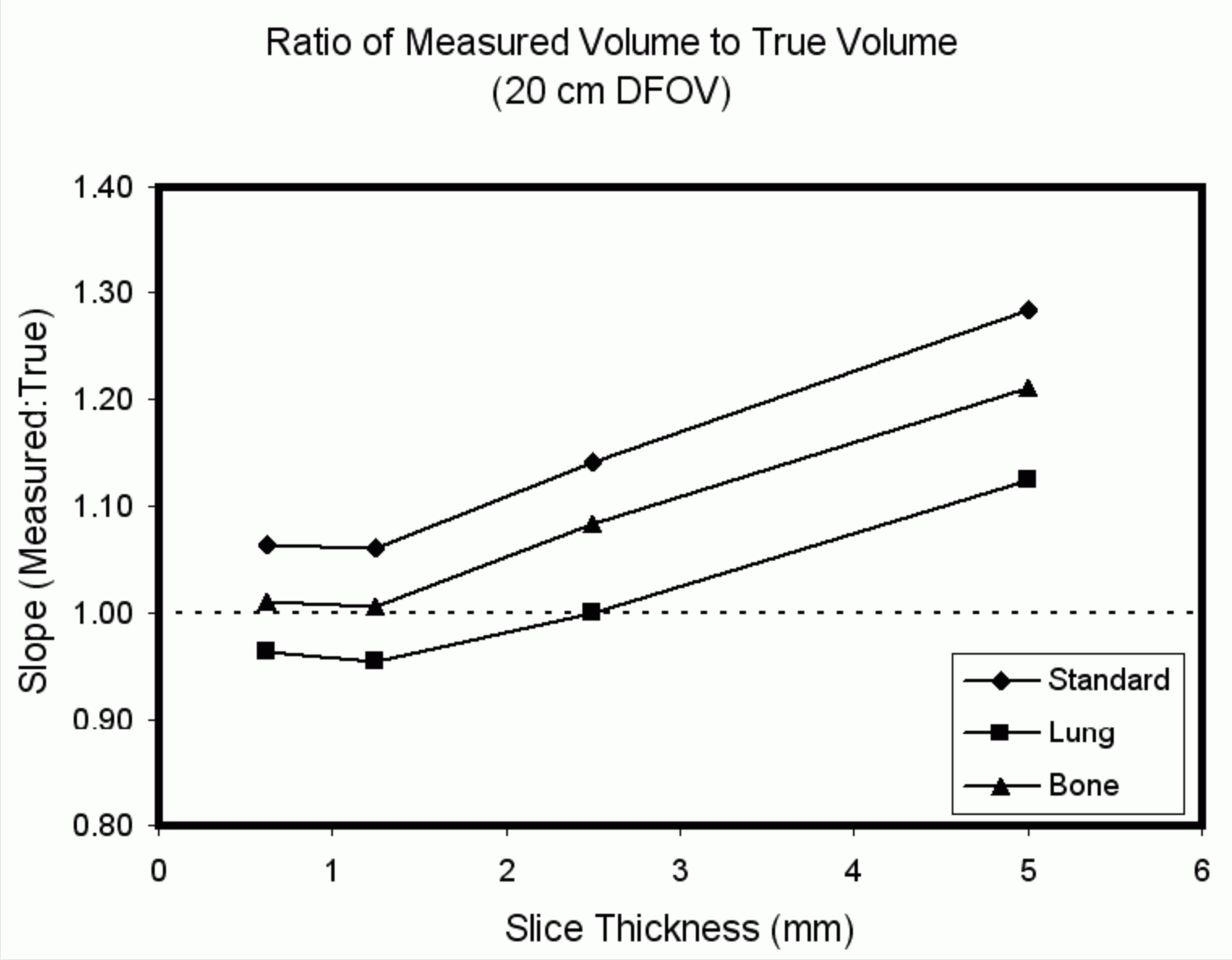




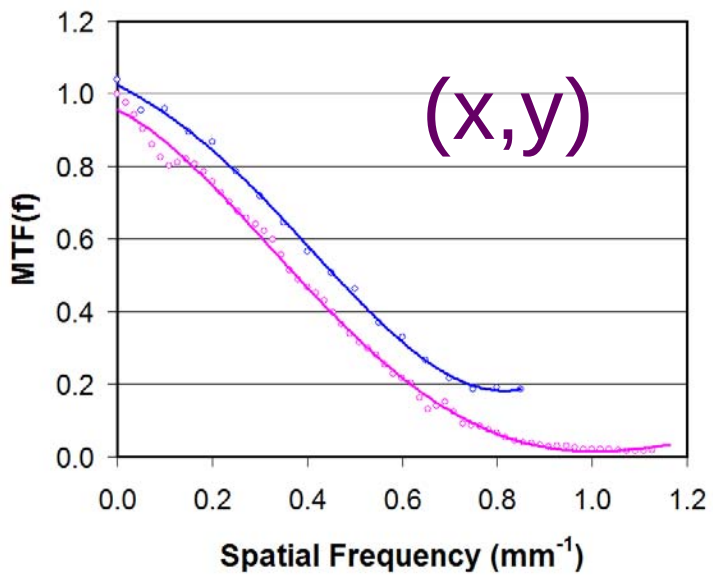


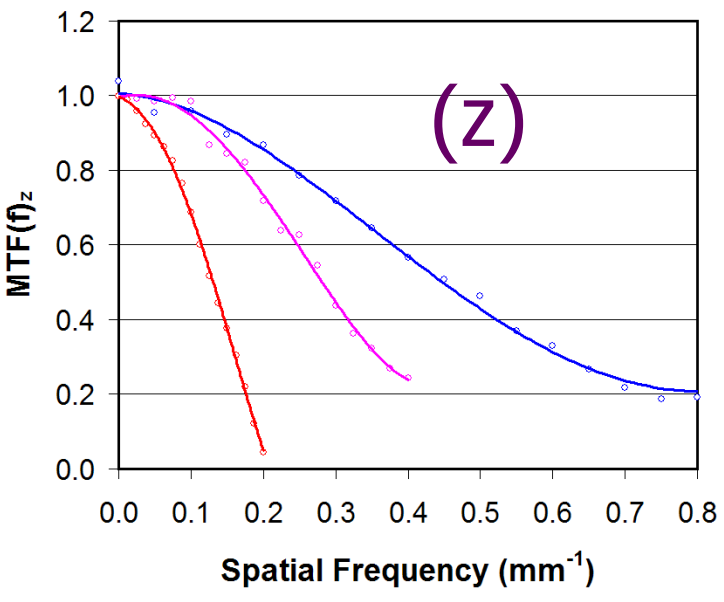


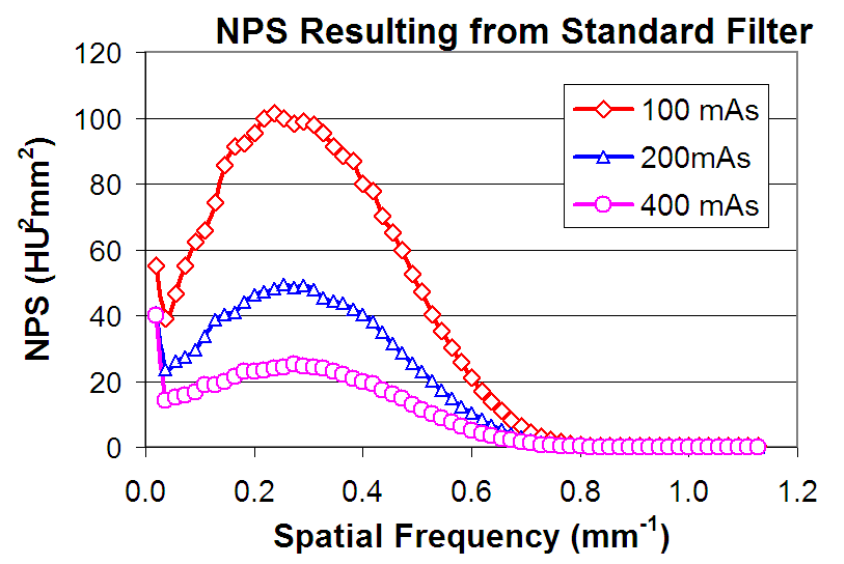

Standard Kernel, 30 cm DFOV
Measured Volume (mm³)
True Volume (mm³)
0
2000
4000
6000
8000
10000
12000
0.625 mm
1.25 mm
2.50 mm
5.00 mm
Unity

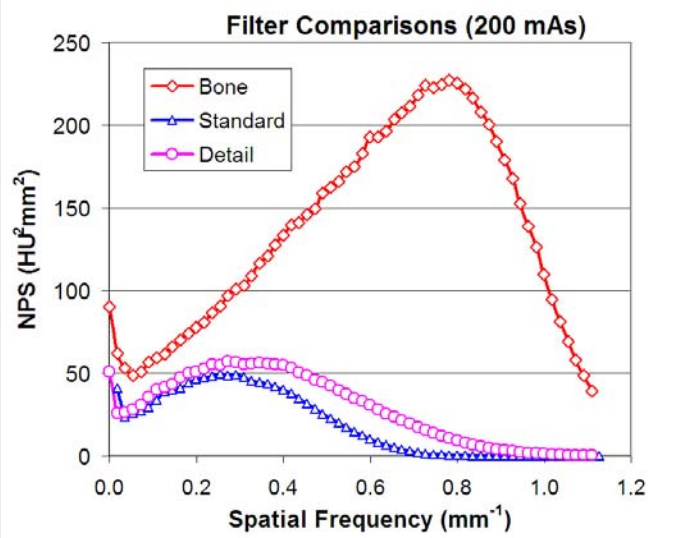

Ratio of Measured Volume to True Volume
(20 cm DFOV)
Slope (Measured:True)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0
1
2
3
4
5
6
Slice Thickness (mm)
Standard
Lung
Bone

MTF(f)


(x,y)
MTF(f)
Spatial Frequency (mm^{-1})

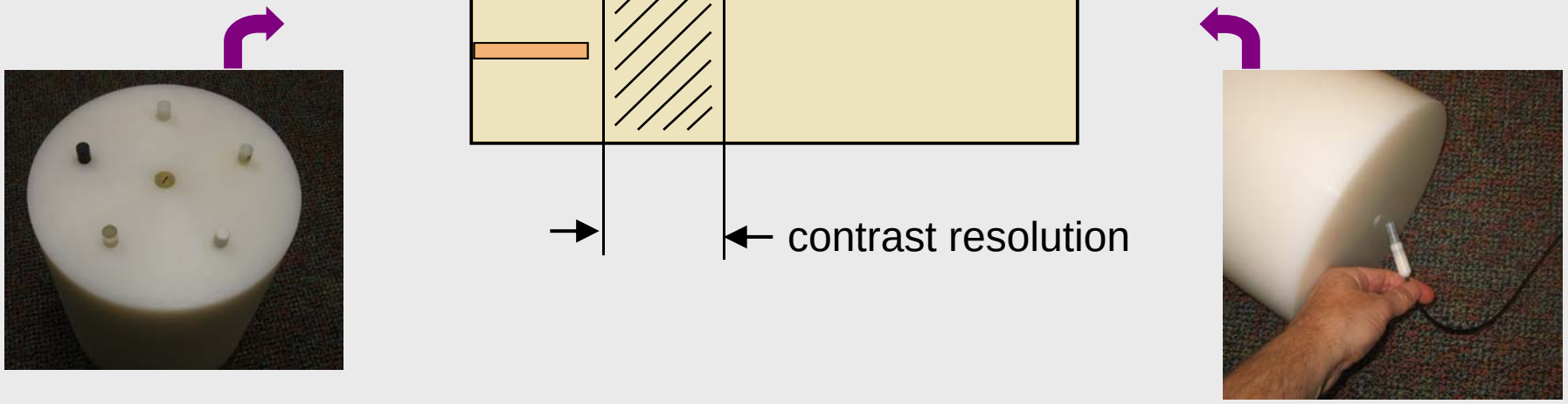

(z)
MTF(f)$_z$
Spatial Frequency (mm^{-1})

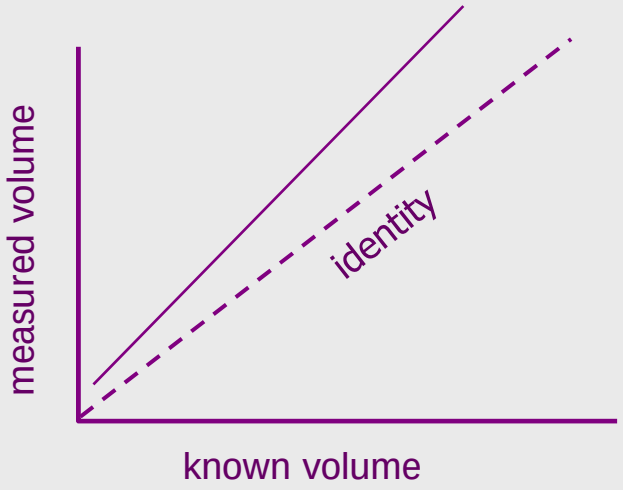

NPS Resulting from Standard Filter
100 mAs
200mAs
400 mAs
NPS (HU^{2}mm^2)
Spatial Frequency (mm^{-1})

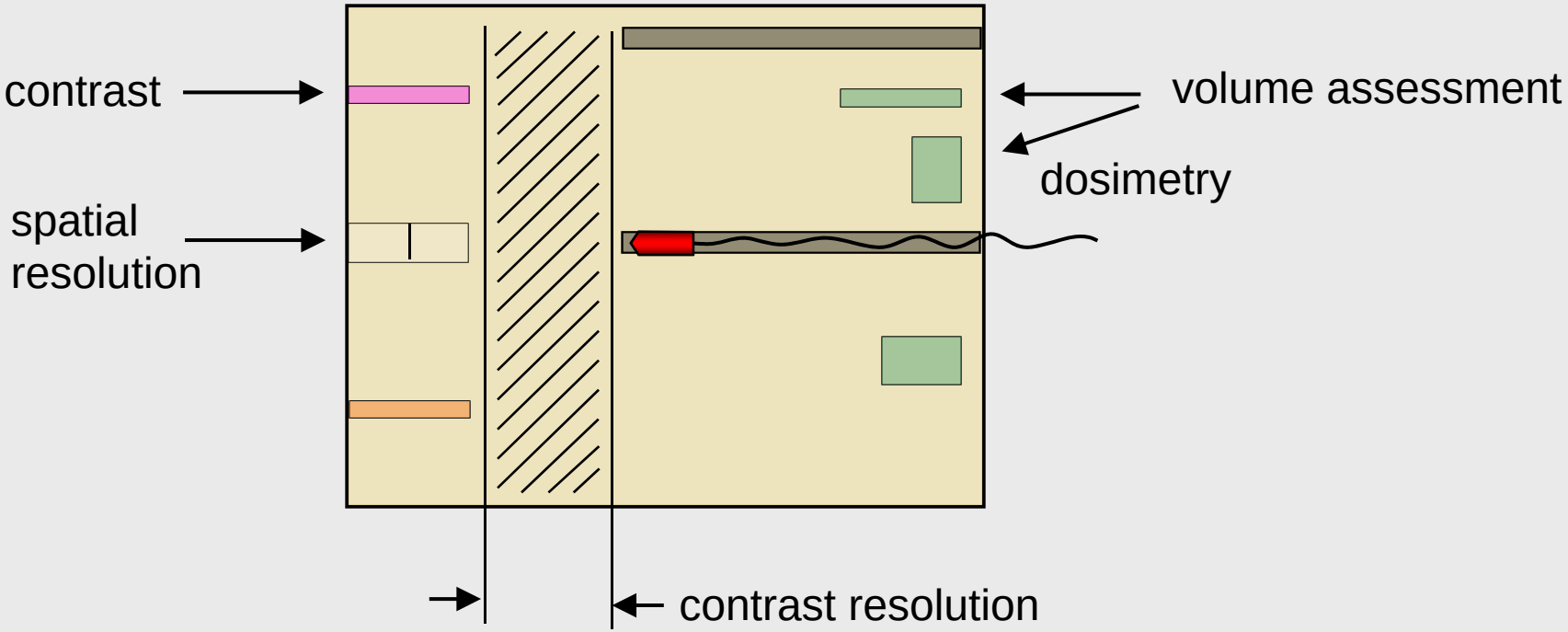

Filter Comparisons (200 mAs)
Bone
Standard
Detail
NPS (HU^{2}mm^2)
Spatial Frequency (mm^{-1})

NPS(f)

International Commission on Radiation Units and Measurements, Inc.




measured volume
identity
known volume


contrast
spatial resolution
volume assessment
dosimetry
contrast resolution

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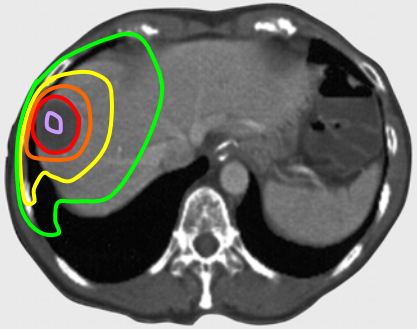

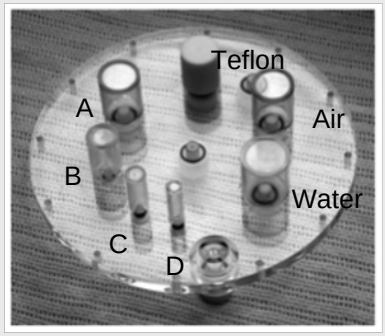

AAPM

RSNA

ASTRO
American Society for Therapeutic Radiology and Oncology