PAT ACR Phantom Analysis

The ACR Phantom Analysis is meant to precisely mimic the required quantitative analysis report that is required to be sent back to ACR for accreditation.

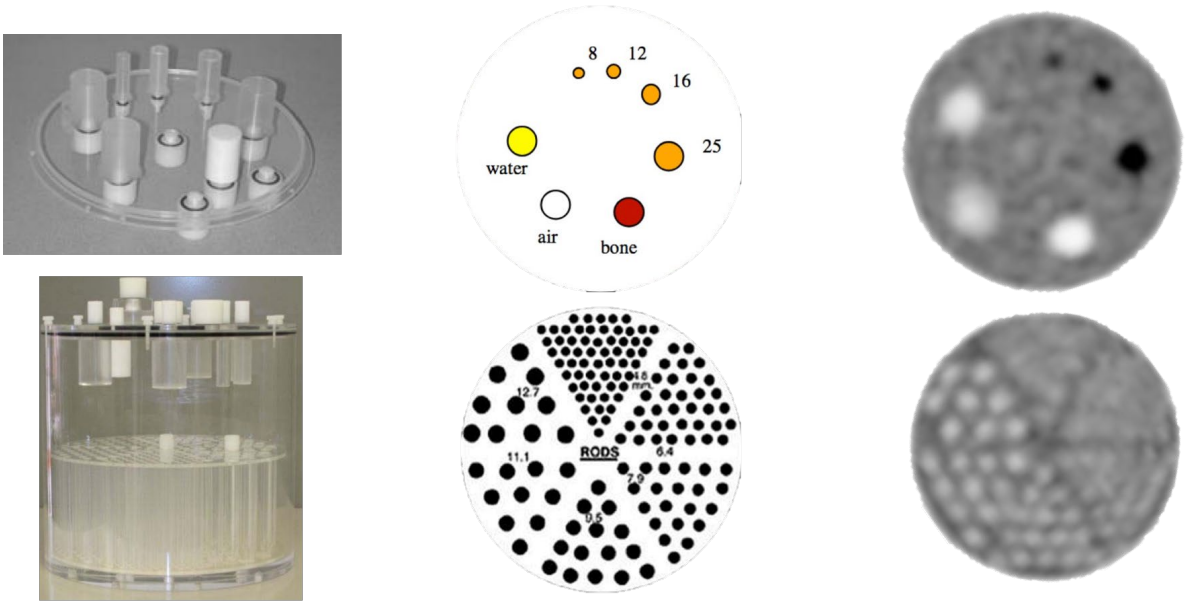

Figure 1. The ACR PET Phantom, its geometry, and typical images.

The ACR Phantom (Figure 1) program is extensively discussed and presented on the ACR website and through ACR publications, and so we will not duplicate this information. Virtually all information can be accessed from https://www.acraccreditation.org/Modalities/Nuclear-Medicine-and-PET

This information not only includes the phantom imaging instructions, but also the ACR PET/CT phantom acceptance criteria.

The PAT ACR module understands the geometry of the ACR PET/CT phantom and automatically locates the 8 mm, 12 mm, 16 mm, and 25 mm hot cylinders and the three cold 25 mm diameter cylinders. The PAT software generates the requisite 1 cm thick slices and draws the ACR required VOIs of the appropriate size.

All ACR requested quantitative data is generated and automatically entered into the ACR data sheet required for submission.

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Understanding the Report

Report Header

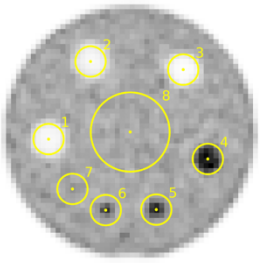
The header of the report is at the top of the first page. Example below (Figure 2)

Facility: ATLANTA VAMC	Phantom: ACR	Contrast: 2.4:1
Scanner Model: SIEMENS Biograph64	Scan: 12/15/2011	Time Per Bed: 3.5min.
Reconstruction: PSF+TOF 2i21s Gauss3.00		

Figure 2. The Report Header

This Section reads the facility name, scanner make and model, reconstruction, scan date, and time per bed position from the DICOM tags. It also reports the actual contrast in the phantom based upon the reported activity injected into the phantom, spheres, and the phantom volume.

Quantitative Assessment



Contrast				
	Hot Vial 8mm	Hot Vial 12mm	Hot Vial 16mm	Hot Vial 25mm
max. SUV	1.34	2.56	2.83	3.11 ✗

Scatter/Attenuation				
	Background	Bone	Air	Water
mean SUV	1.05 ✓	0.15	0.22	0.18
min. SUV	n/a	0.15	0.08	0.09

Ratio Calculations: max. vial SUV to mean background SUV				
	8mm/bkdg	12mm/bkdg	16mm/bkdg	25mm/bkdg
Contrast	1.27	2.43	2.68	2.95

Ratio Calculations: max. vial SUV to max. 25 mm vial			
	8mm/25mm	12mm/25mm	16mm/25mm
Contrast	0.43	0.82	0.91 ✓

Ratio Calculations: min. air or water to min. bone		
	air/bone	water/bone
ratio	1.98	2.04

Figure 3. ACR PET /CT phantom analysis

At left is a PAT generated ACR analysis sheet (Figure 3). It is formatted identically to the standard ACR data sheet that is supposed to be filled in by the user.

Even though 20 quantitative measurements are required by ACR to be performed by the user, reviewers only look at three pieces of data.

First, the "Hot Vial 25 cm" SUV_{max} must be between 1.8 and 2.8. If the value falls within this range, a green check mark is automatically generated. A red X is automatically placed in that box in Figure 3 because it is outside of ACR's acceptance bracket. Interestingly, this data was taken on a well calibrated new SiPM array PET/CT scanner using the manufacturer's most advanced clinical reconstruction. As this reconstruction appears to overcorrect for partial volume (as many of these advanced reconstructions do), it results in an out of range value.

Second, the SUV_{mean} of the background (equal to 1.0 if the fill was performed correctly) must be between 0.85 and 1.15. This is an overly generous acceptance for calibration, as every other accrediting body only allows a ± 10% calibration error, and most PET scanners can easily maintain a ± 5% accuracy. With this is mind, the PAT software generates a green check mark if the

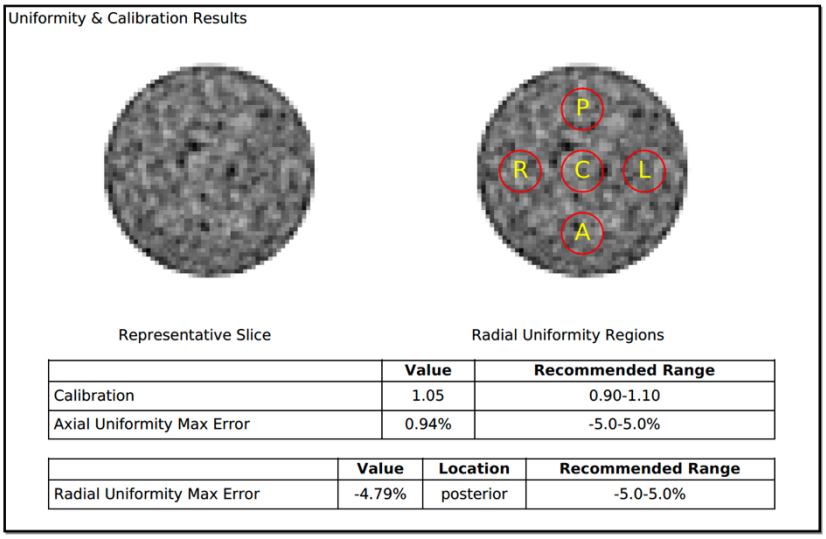
calibration is within the ± 10% window, but a yellow warning icon is displayed if the SUV_{mean} is between 10-15% discrepant from the expected calibration. If the calibration is off by more than 10%, the scanner should be recalibrated.

The third quantitative measure is the ratio of the 16 mm cylinder SUV_{max} to the SUV_{max} of the 25 mm cylinder. This ratio must be greater than 0.7. If it meets this criterium, a green check mark is generated.

None of the other 17 quantitative measurements have been officially reviewed by ACR reviewers for more than a decade. As PAT stores all of this data electronically, it affords an opportunity to collect this data in an organized fashion, and to perhaps determine more empirically derived criteria for acceptable performance in the future.

Image Uniformity/Calibration

A crude assessment of image uniformity is performed using the small uniform region in the center of the phantom. This is of limited utility given that only a handful of slices with uniform background are available for this assessment. This region is also used for the calibration assessment. An example of PAT output of Calibration and Uniformity is illustrated in Figure 4.



	Value	Recommended Range
Calibration	1.05	0.90-1.10
Axial Uniformity Max Error	0.94%	-5.0-5.0%

	Value	Location	Recommended Range
Radial Uniformity Max Error	-4.79%	posterior	-5.0-5.0%

Figure 4. Calibration and Uniformity output.

System Resolution/High contrast Resolution

Image resolution is to be determined from the smallest resolution pattern resolved in a 1 cm thick transaxial slice. A representative 1 cm this slice is provided.

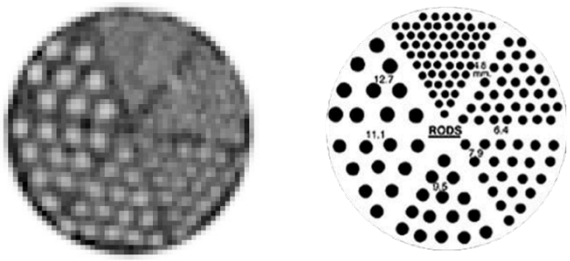


Figure 5. A representative 1 cm thick slice from which the smallest resolved rod pattern can be identified.

Image Quality/Lesion Detectability

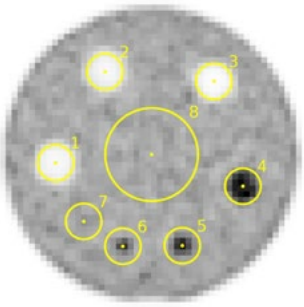


Figure 6. 1 cm thick slice used for low-contrast lesion detectability.

The low contrast lesion detectability test requires The 12 mm diameter cylinder (ROI 6 in Figure 6) must be visually discernable by the reviewer to meet ACR acceptance criteria.

DICOM and Fill Information

Relevant DICOM header and fill information is displayed in fourth box (Figure 7). This is included to provide a simple means to check the fill and reconstruction information.

	Name	Value
	Institution	ATLANTA VAMC
	Phantom	ACR
	Series Description	PET WB 4min TrueX+TOF
	Scan Date	12/15/2011
	Scan Time	15:48:21
	Assay Time	14:47:43
	Patient Dose	10
	Background Volume	5660.0g
	Background Activity	0.83
	Uptake Time	84.35
	Cylinder Solution Volume	1000.0g
	Cylinder Activity	0.35
	Actual Contrast	2.40:1
	Minutes per Bed	3.50
	Voxel Dimensions	4.07x4.07x4.00mm
	Matrix Dimensions	200x200x90
	Scanner Make and Model	SIEMENS Biograph64
	Reconstruction Method	PSF+TOF 2i21s
	Reconstruction Parameters	
	Reconstruction Filter	XYZ Gauss3.00

Figure 7. DICOM header and ACR Phantom fill information