



Objectives

- We are investigating positron emission mammography (PEM) performance as a function of object activity levels, size, and lesion-to-background uptake ratios.
- Measure detection sensitivity on phantom spheres and patient lesions as a function of image count statistics

Methods

- PHANTOMS were made using saline bags (18 cm X 13 cm) as uniform background (BG), and plastic spheres filled with activity concentration above BG to mimic lesions.
- Table 1 gives the BG activity concentrations, sphere sizes, and the ratio of sphere-to-BG activity concentrations (referred to as 'lesion-to-BG ratio' (LBR)) used.
- A fixed detector separation of 8.5 cm was used. This represents a slightly larger than average detector separation based on a sample of 93 PEM patients (mean separation = 7.2 cm, range: 3.5-13.1 cm)¹ Wang et al., *AJR* 197 Aug.2011 in press DOI:10.2214/AJR.11.6478.
- There were a total of 108 phantom images:
 - 99 BG conc./sphere diameter/LBR combinations (Table 1, one omitted)
 - 22 images had two spheres
 - 14 sphere types (diameter/BG/LBR) were repeated on two-sphere images
 - 17 images had zero spheres

Sphere diameters =	4, 8, 12, 16, 20 mm
BG act. conc. (18-F) =	0.44, 0.93, 1.9, 2.8, 4.1 kBq/mL
Lesion:BG ratio (LBR) =	3, 5, 11, 21
All combinations (except one) were used yielding 99 spheres	

- Phantoms were scanned for 7 min. on the PEM Flex Solo II, Naviscan, Inc.^{2,3}
- ²MacDonald et al., *JNM* 50(10):1666, 2009. ³Luo et al., *IEEE-TNS* 57(1):94, 2010.

- Phantom activities correspond roughly to patient injected doses as given by Table 2

Table 2

Injected Dose MBq (mCi)	Patient mass (kg)				
	50	60	70	80	90
555 (15)	7.61	6.34	5.43	4.75	4.23
370 (10)	5.07	4.23	3.62	3.17	2.82
278 (7.5)	3.80	3.17	2.72	2.38	2.11
185 (5.0)	2.54	2.11	1.81	1.58	1.41
93 (2.5)	1.27	1.06	0.91	0.79	0.70
46 (1.25)	0.63	0.53	0.45	0.40	0.35

Shaded cells are values within range of concentration used in phantom experiments
Adjust for other SUV by multiplying by the desired SUV value in g/mL units

- PATIENTS (n=5) with confirmed infiltrating ductal carcinoma (IDC) underwent FDG-PEM scanning as part of an IRB-approved, HIPAA compliant study into reduced dose PEM;
- 202 ± 7.2 MBq (5.5 ± 0.2 mCi) FDG was injected,
- followed by single-view 14-min PEM scans at 60, 90, and 120-min post-inj.
- Images were reconstructed using 100%, 50%, and 25% of the total acquired counts.
- Results were compared to final pathology reports.

- READER SCORING used the following scale

- 1 = "almost definitely not present"
 - 2 = "probably not present"
 - 3 = "unsure"
 - 4 = "probably present"
 - 5 = "almost definitely present"
- scores 3, 4, 5 were considered positive for sensitivity calculations

- Readers observed all 12 PEM image slices, free to zoom and change color map & windowing

- 7 phantom readers (3 MQSA, 3 NucMed, 1 both)
- 5 patient readers (2 MQSA, 2 NucMed, 1 both)

Results

Fig. 1. Phantom Image Samples

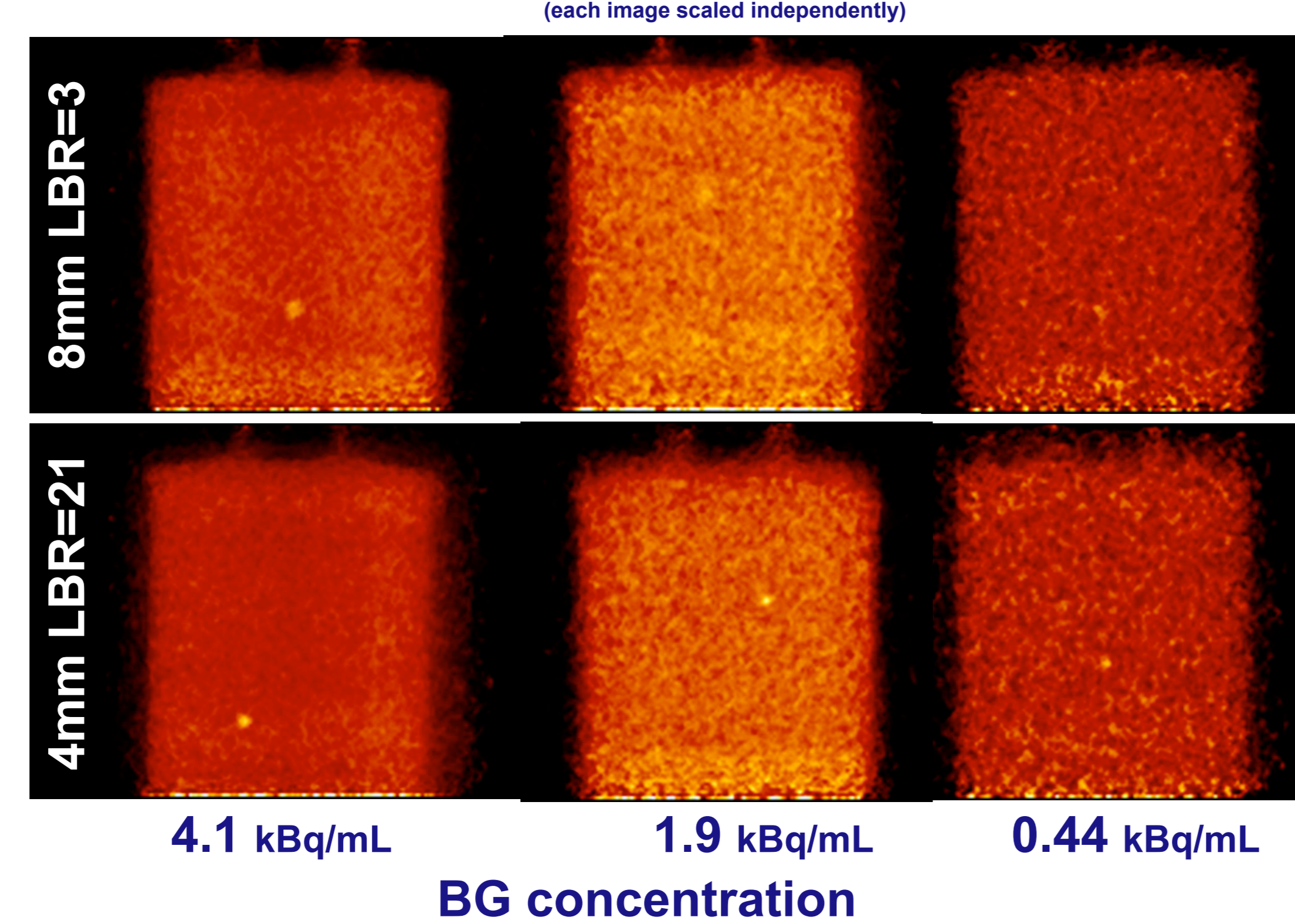


Fig.2. Phantom Statistics

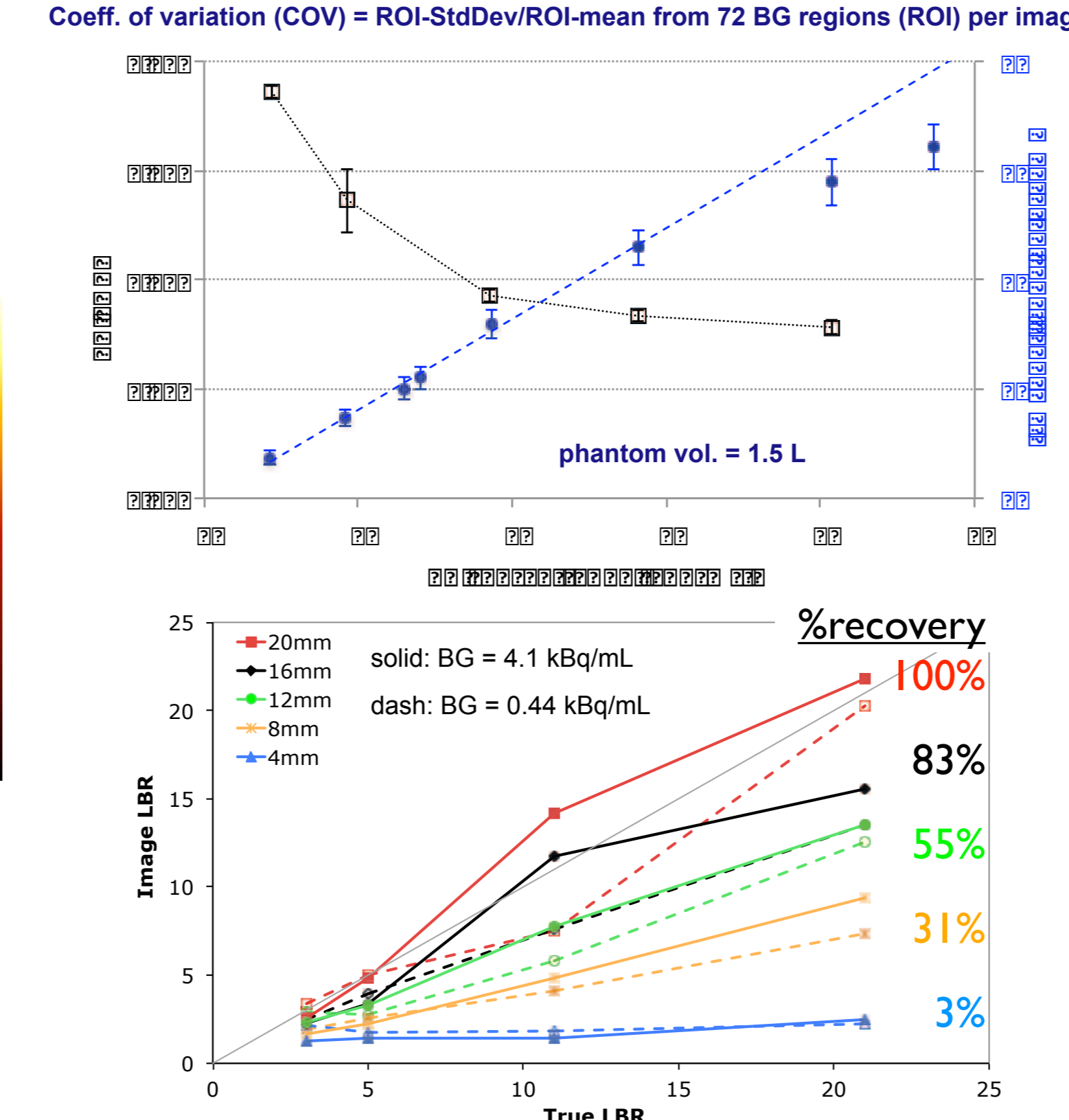


Fig.4. Patient 1

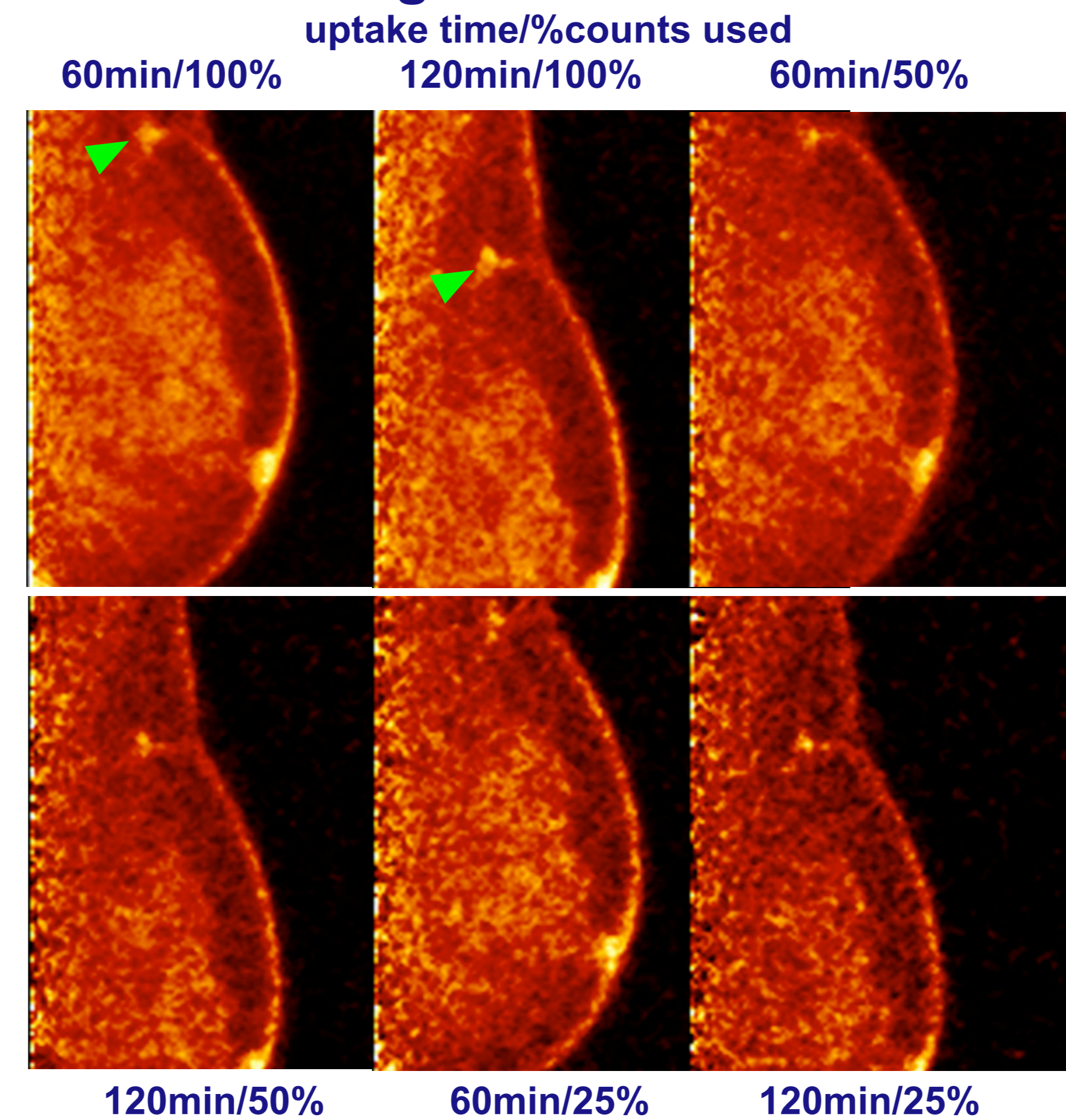


Fig.3. Reader Scores: PHANTOMS

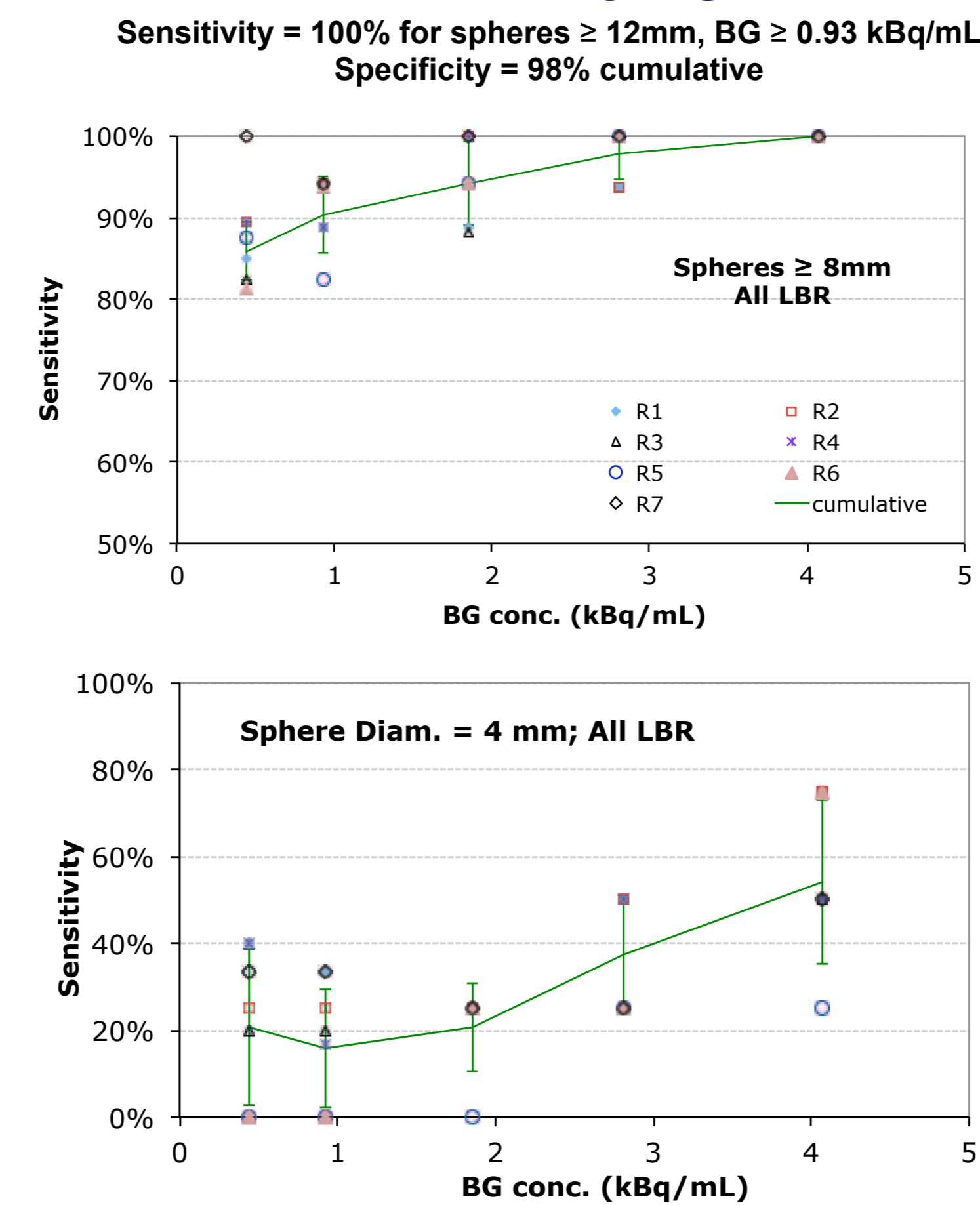


Fig.5. Reader Scores: Patient 1-2 cumulative

Sensitivity = 100% for patients 3-5 (see fig. 6)

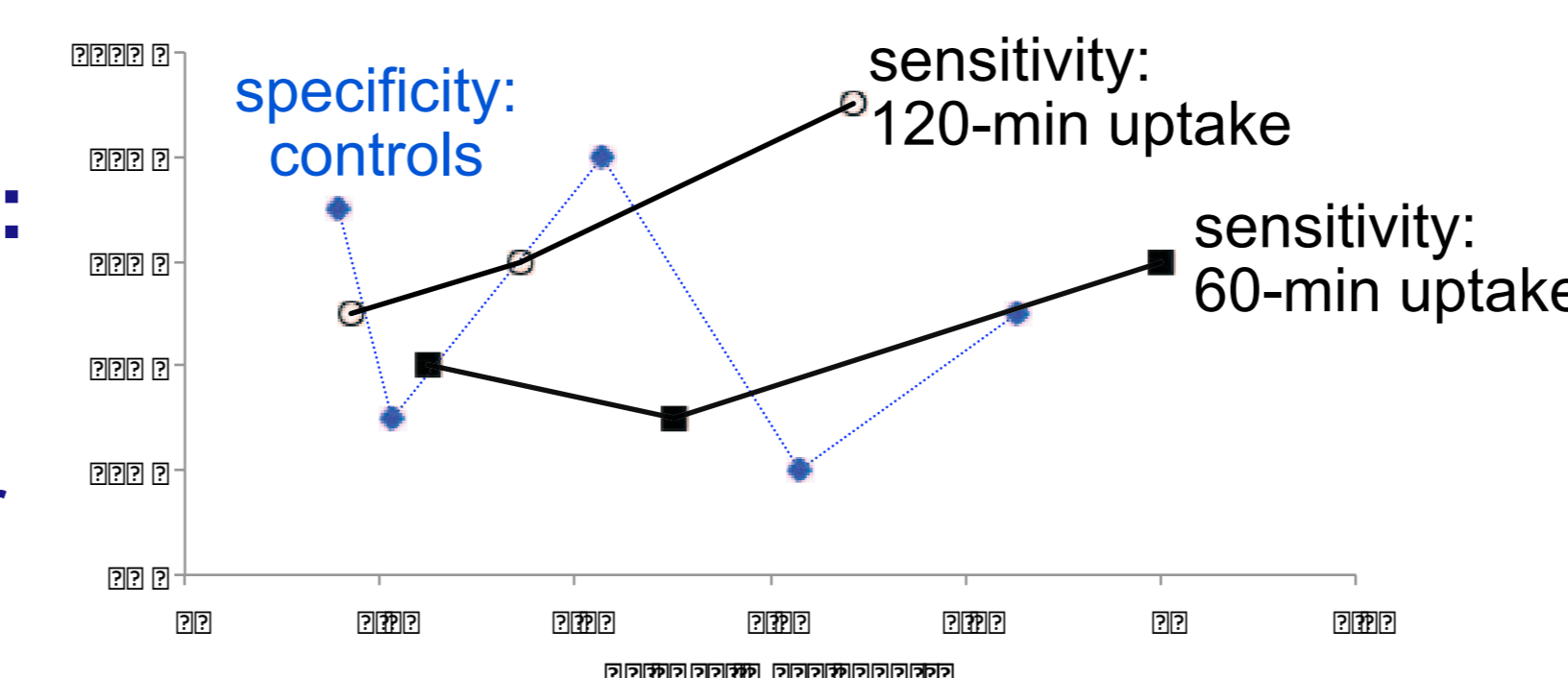
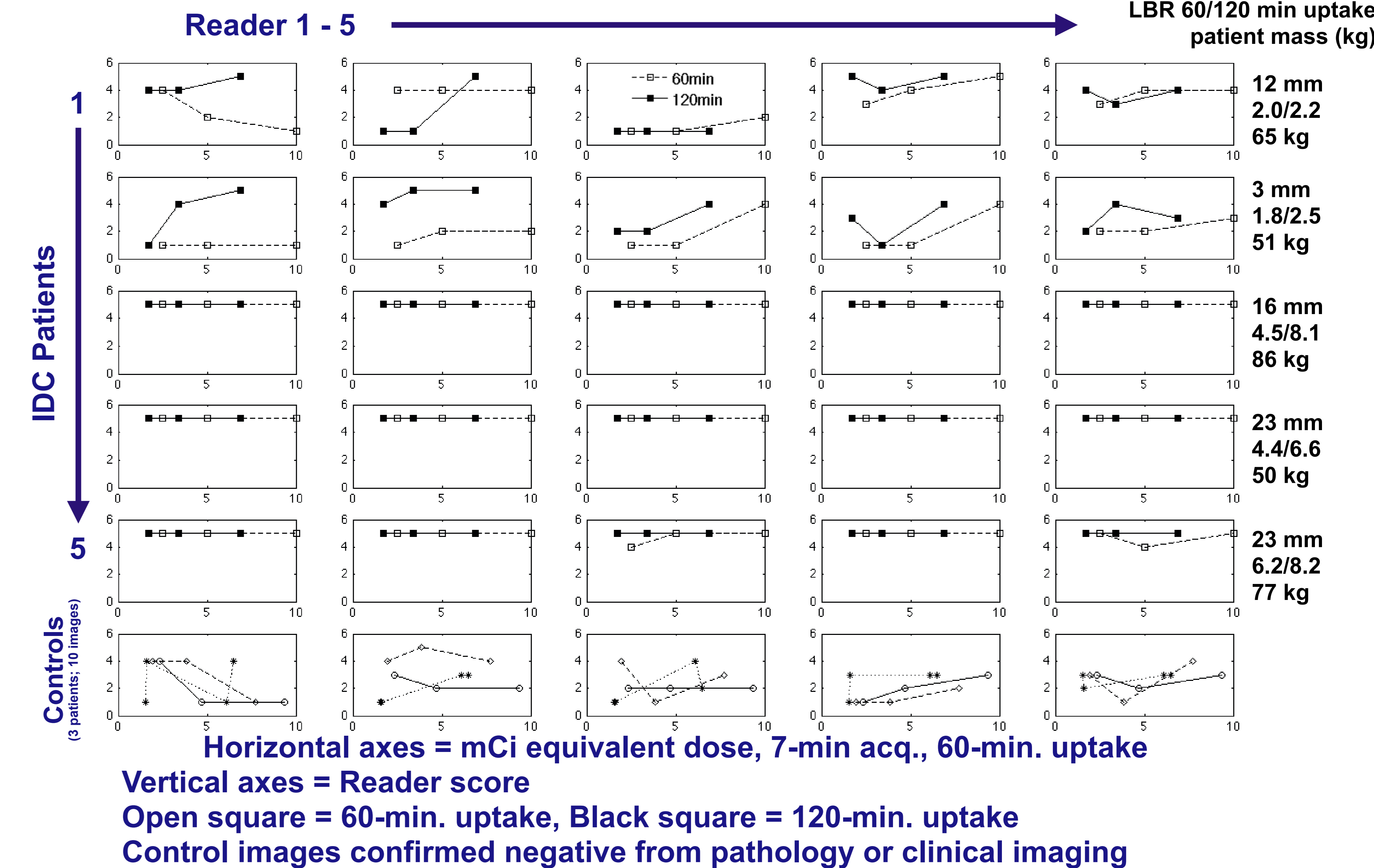


Fig. 6. PATIENT Reader Scores vs. Relative Dose



Conclusions & Remarks

- As with whole-body PET, general nuclear medicine, and CT scanning, image quality and detection sensitivity depend on photon counting statistics in PEM imaging.
- LBR measured on PEM images was strongly dependent on lesion size (fig. 2), as is also the case in WB-PET; here contrast recovery is only 3% for 4mm diameter spheres, suggesting that detection of such lesions requires a relatively high true LBR (eg 20) and will depend on the heterogeneity of the surrounding tissue.
- The relationship between injected dose and BG concentration (& thus uniformity & sensitivity) depends on patient mass, uptake time, and image acquisition time; for 60-min uptake, 10-min scan time, and patients < 100kg, a 185 MBq (5 mCi) injection yielded 95% detection sensitivity for spheres >= 8mm, and 100% for spheres >= 12mm in phantom studies. Injected dose could be reduced further for lighter patients, and/or with concordant increased scan time.
- Sensitivity on patient images was 100% for lesions > 15mm and measured LBR > 4, regardless of counting statistics (fig. 6).
- Increased 18-F-FDG uptake LBR in IDC over time can improve detection sensitivity more than increased count statistics (fig. 5). Note that increased uptake time reduces scan-time activity due to decay.
- Uniform phantom BG is not a good surrogate for determining specificity due to heterogeneous 18-F-FDG uptake in normal breast tissue (cf. patient specificity (fig. 5) and phantom specificity (fig. 3)).
- Phantom results require further sorting as a function of sphere LBR, and reader experience.