# I-123 SPECT: task groups

- **Literature Review:  Seibyl**
- **Claim Formulation**
- **Clinical**
- **Image Acquisition & Processing: Dewaraja**
- **Phantoms/ DRO: Dickson & Zimmerman**
- **Quantitative & Image Analysis: Seibyl & Miyaoka**
- **Conformance (aka compliance)**

# DAT Scan Image Acquisition: Camera, Collimator

- Multiple detector systems or dedicated brain [1]
- High-resolution collimators:LEHR,LEUHR, Fanbeam.
  - Specification for SPECT spatial resolution used in [2 ]:
    FWHM < 15 mm at 15 cm ROR. (included LEGP)
  - ME may not be sufficient. But, in a simulation study (relevant to thyroid cancer imaging) it was shown that I-123 with a ME collimator, which reduces high energy penetration, gave better contrast recovery than LEHR when TEW scatter/penetration correction was NOT used [3]. In this study, resolution with LEHR was 10.8 and with ME was 12.6 mm (FWHM).
  - I-123 specific collimators in Japan (need reference). 3 vendors.
  - PPMI trial. No technical publication yet.

# DAT scan: Image acquisition contd.

- Photopeak window: 159 kev +- 10%.  Scatter windows: 133 – 143 keV, 178.5 – 189.5 kev
- Rotational radius: small as possible. Typically, fixed at 11 – 15 cm [2][4][7]
- 128 x 128 matrix. Matrix and zoom to give pixel size 2 – 3 mm [2][4] 3.5 – 4.5 mm [5][7]
- Angular sampling <= $3^0$ ($360^0$ rotation). At least 120 views.  [2][4][5][6][7]

# DAT scan: Image acquisition contd.

- Continuous mode acquisition
- Acquisition time: adjusted to obtain 1.5 million [4,7], ~ 2 million [2][4] or > 3 million [6] photopeak counts. Typically ~ 30 min
  - Can segment into multiple sequential acquisitions to evaluate patient motion and exclude data with artifacts [6]. University of Michigan protocol (Siemens protocol?): six 5 min acquisitions – check for motion and then sum. Not recommended due to low counts (Seibyl, Dickson)

# DAT Scan: Image Reconstruction

- **Iterative reconstruction**
  - Past studies: OS-EM with 10 iterations 10 subsets for sets of 120 projections – high number of iterations for quantitative accuracy [2][4]
- **Scatter correction**
  - Scatter and septal penetration correction using TEW method – scatter estimate can be subtracted from photopeak projections [2][4], but better to include scatter estimate in the reconstruction model. See for example TRODAT study by Cot et al [8].
  - Transmission Dependent Convolution Subtraction (TDCS) method used extensively in Japan
    - Include a correction to the pixel-by-pixel scatter fraction expression (k(x,y)) to account for I-123 high energy penetration [9]
    - Practical because it was shown that a transmission measurement is not needed as good results obtained assuming constant mu value [9][10]
- **Attenuation Correction**
  - homogeneous correction with constant mu. Head outline from edge detection of reconstructed emission image [9][10] or ellipse (?) [2,4]
  - CT based mu map – very low dose CT ( < 10 mA) adequate if only for att corr.
- **Post-filtering**
  - 3D post-filtering using a Butterworth filer [2][4][6][7]

# DAT scan: Image reconstruction contd.

- Resolution recovery
  - In [5] resolution recovery is not recommended as it produces artifacts. Resolution recovery not used in [2][4]?
    - Too many artifacts – not recommended (Seibyl, Dickson)
  - The phantom study for the Tc-99m-ligand (TRODAT) [8] showed that point-spread function (PSF) correction plays a major role in quantification of striatal uptake compared with the attenuation correction and scatter correction. Their 3-D OS-EM reconstruction incorporated the distance depended collimator-detector response into the transition matrix. With all corrections (scatter, attenuation, PSF), the striatal phantom specific uptake ratio was within 96 – 97% of the truth.

# References related to acquisition & reconstruction


1. Varrone et al. Comparison between a dual-head and a brain-dedicated SPECT system in the measurement of the loss of dopamine transporters with [123I]FP-CIT. Eur J Nucl Med Mol Imaging. 2008 Jul;35(7):1343-9.
2. Varrone A, Dickson JC, Tossici-Bolt L et al. European multicentre database of healthy controls for [123I]FP-CIT SPECT (ENC-DAT): age-related effects, gender differences and evaluation of different methods of analysis. Eur J Nucl Med Mol Imaging. 2013 Jan;40(2):213-27.
3. Rault E et al. Comparison of image quality of different iodine isotopes (I-123, I-124, and I-131). Cancer Biother Radiopharm. 2007 Jun;22(3):423-30.
4. Tossici-Bolt L, Dickson JC, Sera T et al. Calibration of gamma camera systems for a multicentre European $^{123}$I-FP-CIT SPECT normal database. Eur J Nucl Med Mol Imaging. 2011 Aug;38(8):1529-40.
5. Datscan Prescribing Information: http://www3.gehealthcare.com/en/products/categories/nuclear_imaging_agents/datscan
6. Darcourt J, Booij J, Tatsch K, Varrone A, Vander Borght T, Kapucu OL, Någren K, Nobili F, Walker Z, Van Laere K**. EANM procedure guidelines for brain neurotransmission SPECT using (123)I-labelled dopamine transporter ligands, version 2.** Eur J Nucl Med Mol Imaging. 2010 Feb;37(2):443-50.
7. Djang DS, Janssen MJ, Bohnen N, Booij J, Henderson TA, Herholz K, Minoshima S, Rowe CC, Sabri O, Seibyl J, Van Berckel BN, Wanner M. **SNM practice guideline for dopamine transporter imaging with 123I-ioflupane SPECT 1.0.** J Nucl Med. 2012 Jan;53(1):154-63.
8. Cot A, Falcón C, Crespo C, Sempau J, Pareto D, Bullich S, Lomeña F, Calviño F, Pavía J, Ros D. Absolute quantification in dopaminergic neurotransmission SPECT using a Monte Carlo-based scatter correction and fully 3-dimensional reconstruction. J Nucl Med. 2005 Sep;46(9):1497-504.
9. Iida H, Narita Y, Kado H, Kashikura A, Sugawara S, Shoji Y, Kinoshita T, Ogawa T, Eberl S. Effects of scatter and attenuation correction on quantitative assessment of regional cerebral blood flow with SPECT. J Nucl Med. 1998 Jan;39(1):181-9.
10. Iida H, Nakagawara J, Hayashida K, Fukushima K, Watabe H, Koshino K, Zeniya T, Eberl S. Multicenter evaluation of a standardized protocol for rest and acetazolamide cerebral blood flow assessment using a quantitative SPECT reconstruction program and split-dose 123I-iodoamphetamine. J Nucl Med. 2010 Oct;51(10):1624-31.

# QIBA meeting at RSNA 2015: summary of discussion

- Questions/discussions
  - 3 levels of compliance for UPICT protocols: ideal, target, acceptable. FDG-PET profile corresponds to **'acceptable'**. Same for SPECT profile?
  - FDG-PET profile has very little details on specifics such as reconstruction parameters . Same for SPECT profile? Dickson adds that SPECT has more variables that are considered standard in PET. So, can add specifics
  - 3 levels of the claim (Frey suggestion): **no corrections**, **with corrections** (constant mu map), **best corrections** (CT-based). (yuni) Perhaps do not need the 'no correction' ?. Dickson adds that for brain imaging 'no correction' still used and may be okay for ratio (SBR)
  - Detector-response compensation very important (Hans, Johannes from Siemens) but what about artifacts (mentioned by Seibyl, Dickson in past call)? Dickson adds that experience only with GE Evolution – may not be true for other systems.
  - Mozley: task groups should start writing. Assign people different sub sections and then chair consolidates
  - Do we have sufficient phantom results to formulate claim on SBR or do we need QIBA sponsored subproject to generate phantom results

# Phantom results: measured vs. true SBR

- **Consensus claim** – not yet substantiated by studies that conform to the given specifications.

- Do we need more phantom studies **before** the profile?
  - Possible QIBA sponsored sub-projects looking at measured vs. true SBR

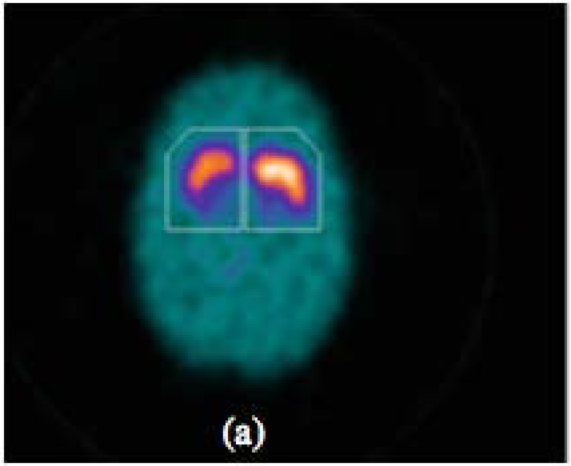
- **Existing Phantom Results**
  - Model based compensation on quantitative 123I brain SPECT imaging. Du, Tsui, Frey. PMB 2006
    - Model based down SC, CT-based AC, post-recon PVC using geomeric transfer matrix
    - Putamen, Caudate Absolute quantification: w/o correction: better than 8% with correction: 2%.
    - SPB (same as SBR? Yes) w/o: 6% with: 4% (Eric added: The reason the errors were so small is that they included partial volume compensation. No correction (NC) is without downscatter compensation, but with scatter, attenuation, and CDR compensation.

  - **Calibration of gamma camera systems for a multicenter European 123I-FP-CIT SPECT normal database.** Livia Tossici-Bolt & John C. Dickson et al, EJNMMI 2011
    - Striatal phantom 10:1 up to 1:1, OSEM with no CDR, AC: ellipse and constant mu. SC: TEW.
    - No specific PVC, but accounts for partial volume effects by using a large geometric ROI (Southampton method)
    - SBR within about 10% of truth, but Dickson says problem is that cannot separate caudate and putamen.
  - **Iida striatal phantom results (unpublished)**
    - Striatal phantom. OSEM with AC, SC, PC (TDCS)
    - Large ROI (Southampton method)
  - **Dickson striatal results (unpublished)**
    - Striatal phantom. Commercial reconstruction and analysis (HERMES)
    - With and without corrections. Tight ROI (caudate, putamen) Most relevant for Claim? But high errors (close to 50% error for SBR even with correction)

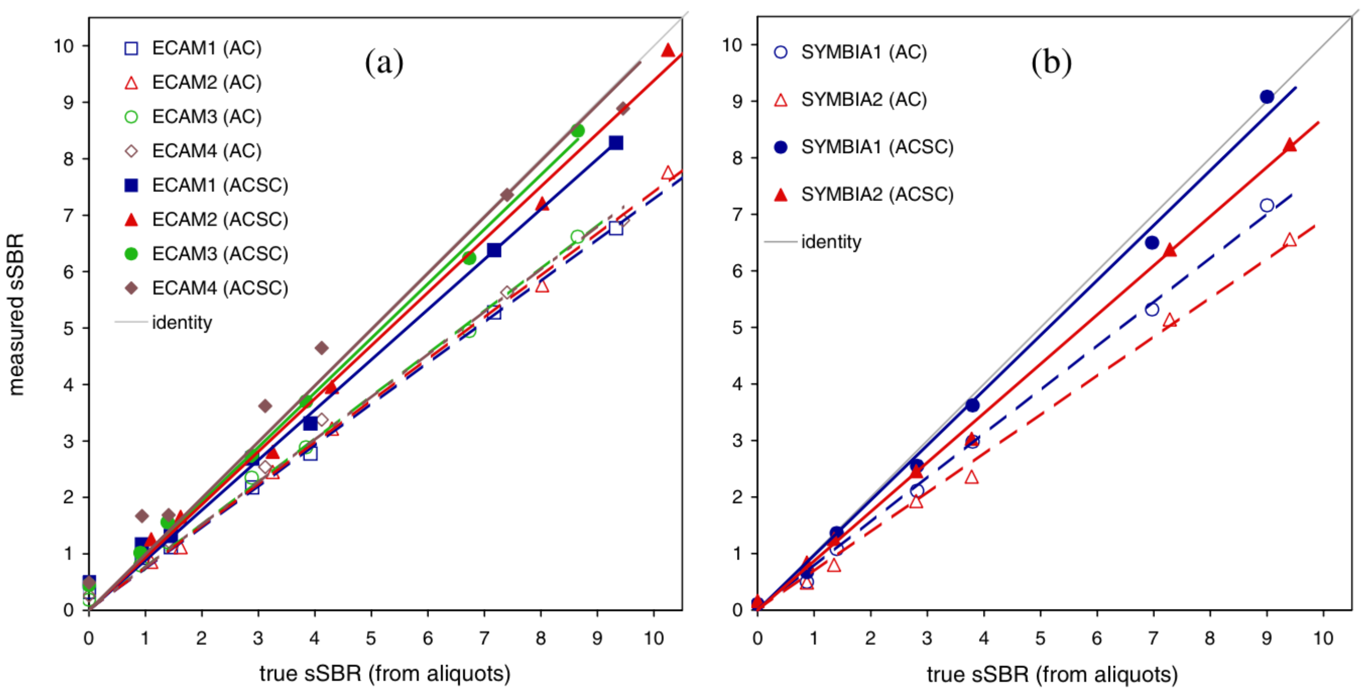
  - **Yong Du, Eric Frey striatal phantom results (unpublished). Comparison of different collimators for DAT scan.** Results presented by Eric not for distribution

# Existing phantom results: measured vs. true SBR

Livia Tossici-Bolt & John C. Dickson et al, EJNMMI 2011



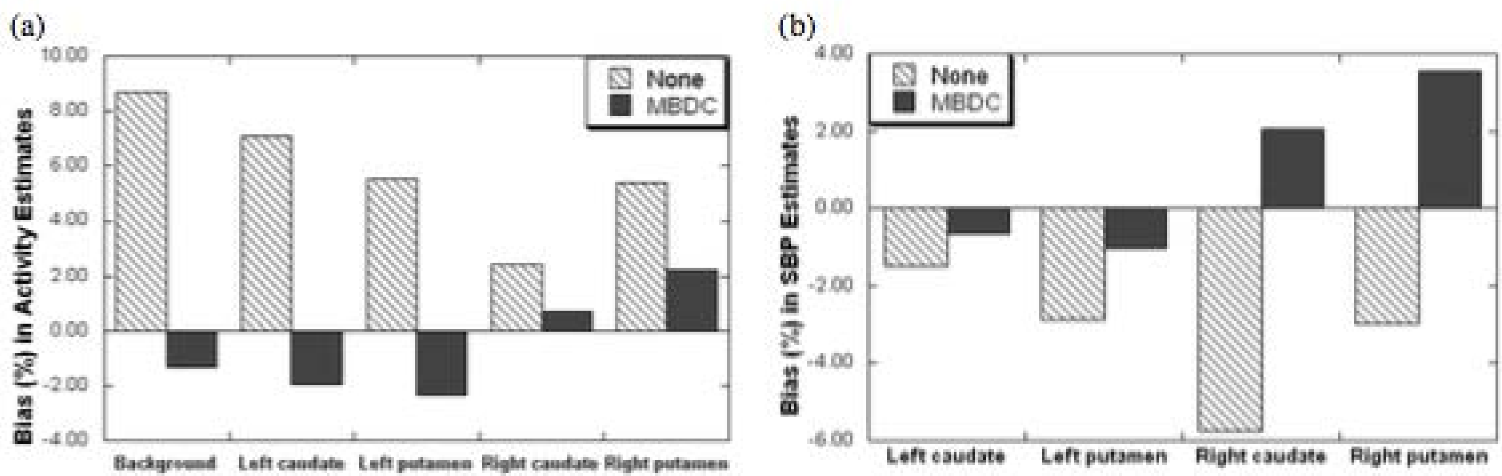

extent, between cameras of the same type. The NC and AC measurements were found to underestimate systematically the actual sSBRs, while the ACSC measurements resulted in recovery coefficients close to 100% for all cameras (AC range 69–89%, ACSC range 87–116%). The COV improved from 46% (NC) to 32% (AC) and to 14% (ACSC) ($p$<0.001).



# Existing phantom results: MC simulation & striatal phantom Du, Tsui, Frey. PMB 2006 (Note: tight ROIs)

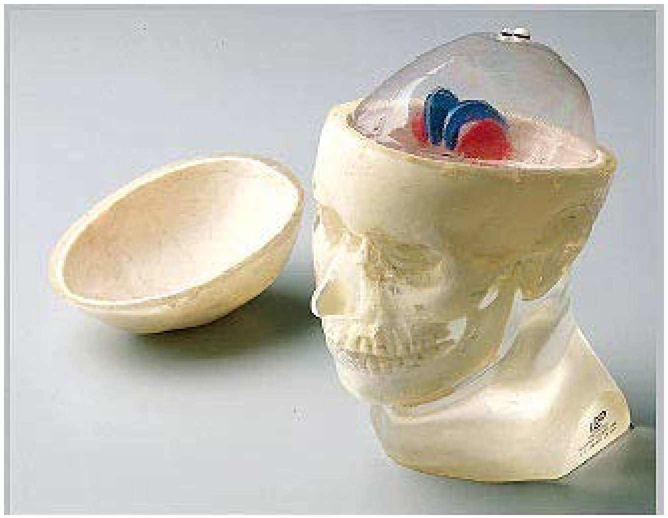
**Table 4.** Per cent bias of striatal SBP from MC data.

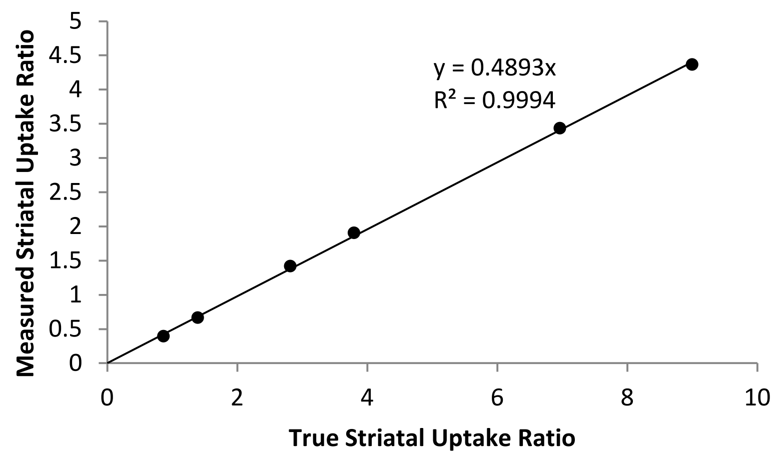
| Distribution | Method | Left caudate | Left putamen | Right caudate | Right putamen |
|---|---|---|---|---|---|
| I | None | −7.46 ± 3.37 | −10.93 ± 3.04 | −7.85 ± 4.11 | −9.46 ± 3.49 |
| | ND | 2.64 ± 3.61 | −0.58 ± 3.29 | 2.96 ± 4.36 | 0.98 ± 3.72 |
| | MBDC | 3.81 ± 3.66 | 0.88 ± 3.34 | 4.30 ± 4.41 | 2.64 ± 3.79 |
| II | None | −5.76 ± 5.25 | −9.14 ± 3.36 | −6.39 ± 5.76 | −7.18 ± 3.33 |
| | ND | 0.81 ± 5.53 | 1.19 ± 3.46 | −0.99 ± 6.07 | 3.26 ± 3.60 |
| | MBDC | 1.91 ± 5.61 | 2.92 ± 3.70 | 0.05 ± 6.14 | 4.87 ± 3.64 |
| III | None | −4.72 ± 5.64 | −7.48 ± 4.65 | −4.50 ± 2.90 | −6.52 ± 2.98 |
| | ND | −0.48 ± 5.14 | −1.68 ± 5.88 | 2.68 ± 2.65 | 1.67 ± 1.13 |
| | MBDC | 0.24 ± 5.85 | −0.55 ± 5.27 | 3.81 ± 3.76 | 2.97 ± 3.27 |




(Eric added: The reason the errors were so small is that they included partial volume compensation. No correction (NC) is without downscatter compensation, but with scatter, attenuation, and CDR compensation

# **Existing phantom results:**
# unpublished results from John Dickson

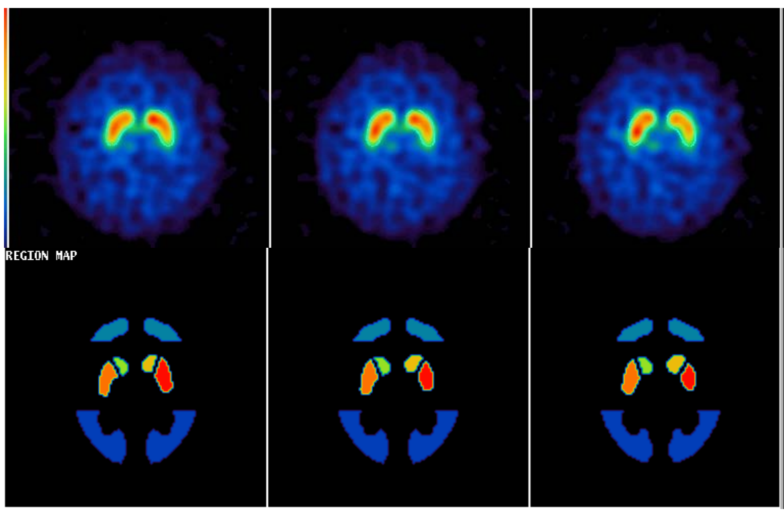





- Striatal Phantom filled with known striatal uptake ratios
- Quantification of image data to determine measured striatal uptake ratio
- Derivation of relationship for each system allows pooling of true striatal uptake ratios

# Existing phantom results: unpublished results from John Dickson with commercial recon/analysis

- Hermes (BRASS)

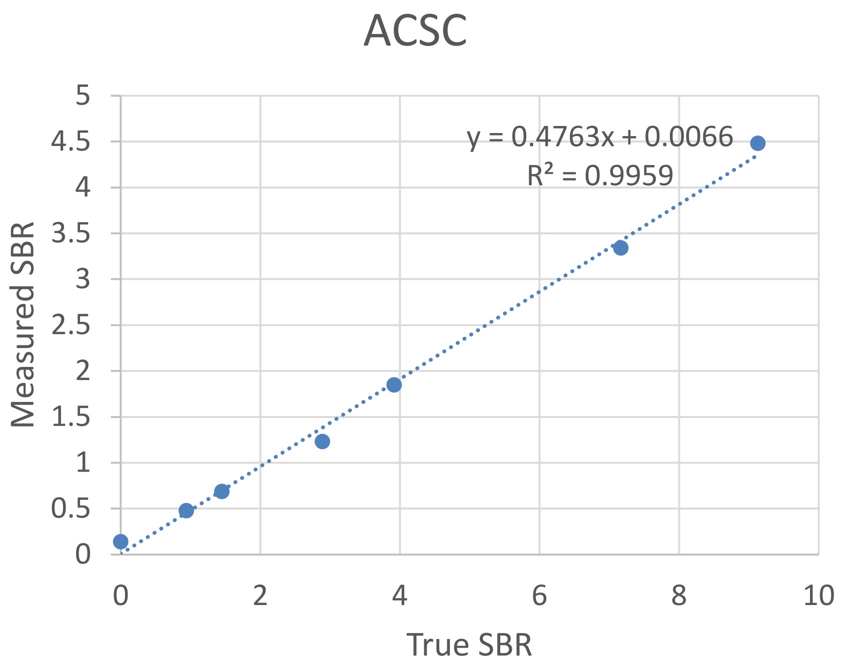


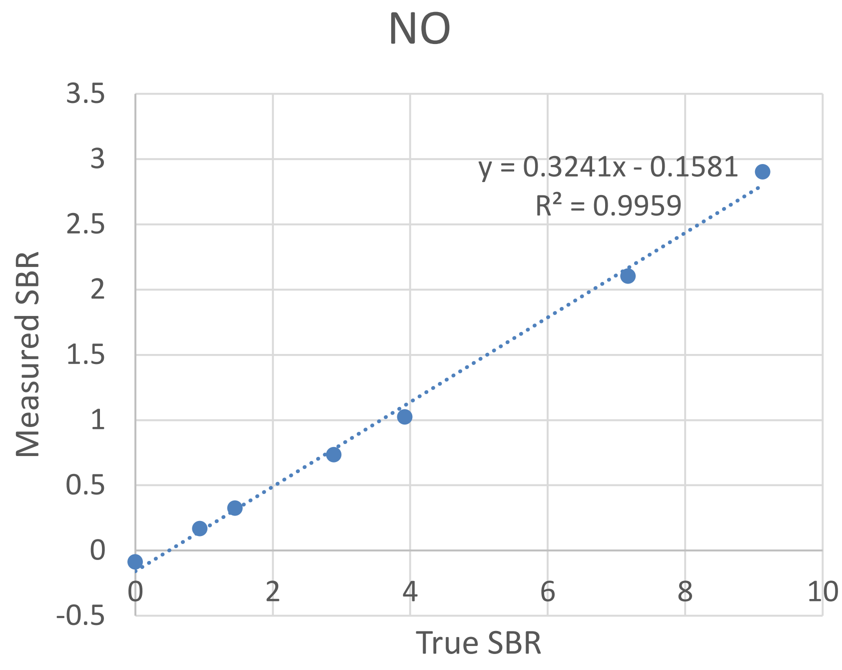

Striatal Uptake Ratio (Caudate/Putamen)

$$\left(\frac{Countperpixel_{Str} - Countperpixel_{Bkg}}{Countperpixel_{Bkg}}\right)$$

# Existing phantom results:

unpublished results from John Dickson
with commercial recon/analysis



# Phantom results from H. Iida (unpublished)

Phantoms :

- Syringe phantom of 30 MBq
- Uniform cylindrical phantom filled with $^{123}I$–solution
- Striatum phantom from Radiology Support Devices

SPECT scan :

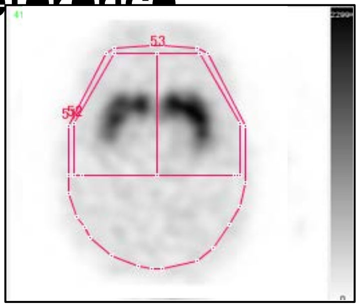
- Experiments for 11 systems at 5 institutions

Reconstruction:

- OSEM with AC (head contour) and SC+PC by transmission-dependent convolution subtraction.
- FBP onsite, with AC but no SC or PC

Quantitation:

- SBR for left and right striatal regions.
  Whole brain activity excluding striatal regions as background.
- Well counter-based SBR as reference



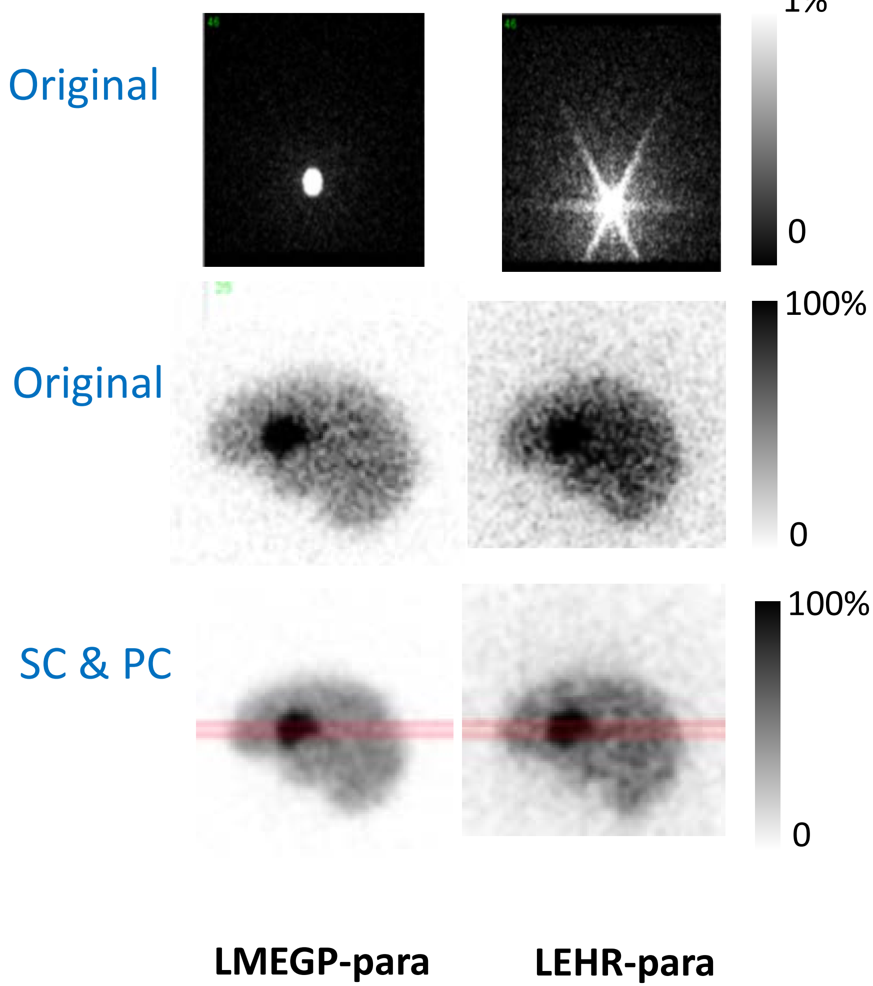

$$SBR = \frac{C_s}{C_r} = \{(\frac{Ct_{str}}{V_{ROI}})/c_r - 1\} \cdot \frac{V_{ROI}}{V_s}$$

# Phantom results from H. Iida contd.

| # | SPECT camera | Collimator |
|---|---|---|
| **1** | Siemens Symbia | LMEGP-para (Siemens Japan) |
| **2** | Philips BrightViewX | CHR-para |
| **3** | GE Infinia | ELEGP-para |
| **4** | | LEHR-para |
| **5** | Toshiba 9300A | LESHR-fan (N1) |
| **6** | Toshiba (Siemens) ECAM | LMEGP-para (Toshiba) |
| **7** | Siemens Symbia | LEHR-para |
| **8** | Toshiba 9300R | LMEHR-fan (N2) |
| **9** | | LESHR-fan (N1) |
| **10** | | LMEGP-para |
| **11** | | LEHR-para |

# Phantom results from H. Iida contd.

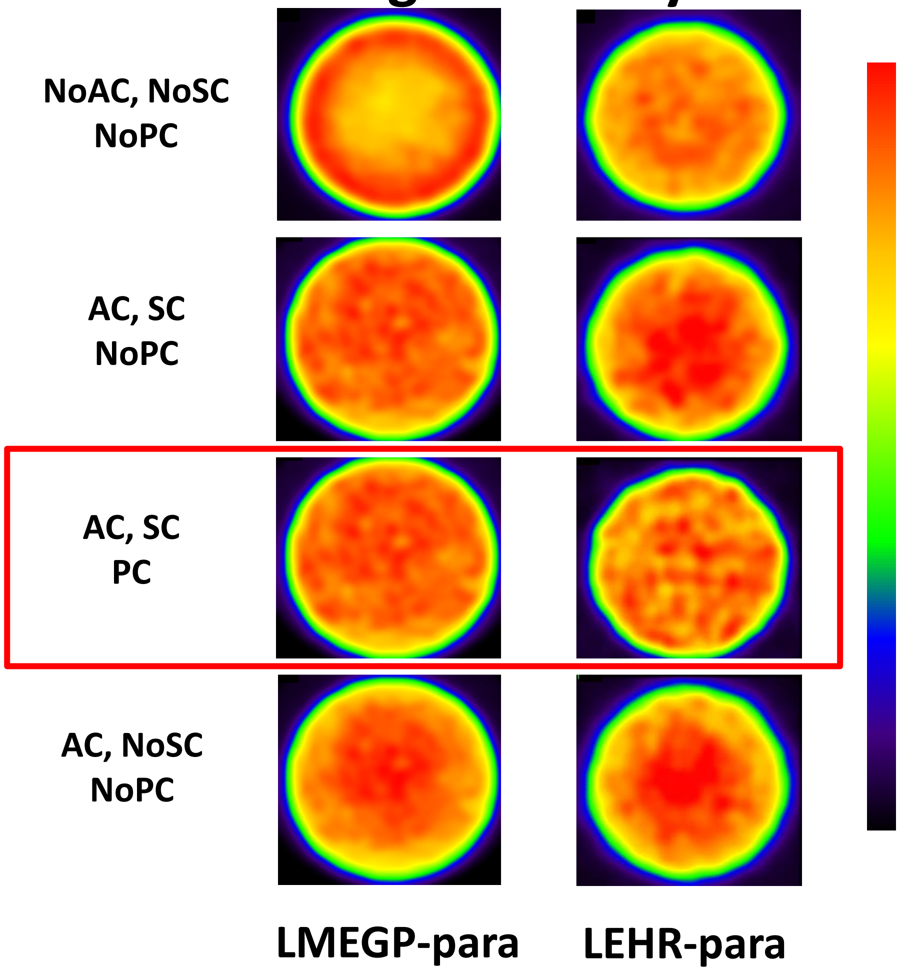
## Example projection from syringe and Striatum phantom experiments




**Siemens ECAM scanner fitted with $^{123}$I-specific (LMEGP-para) and ordinary low-energy (LEHR-para) collimator sets**

# Phantom results from H. Iida contd.

## Example reconstructed images from cylindrical phantom experiments




AC: Attenuation correction
SC: Scatter correction
PC: penetration correction

**Siemens ECAM scanner fitted with $^{123}$I-specific (LMEGP-para) and ordinary low-energy (LEHR-para) collimator sets**

# Phantom results from H. Iida contd.

## Results from Striatum phantom experiments (unpublished)

OSEM with AC, SC, PC

FBP with AC, but NoSC, NoPC

# Phantom results from H. Iida contd.

## Factors which need to be taken into account

- Attenuation correction and scatter correction
- Correction for penetrating photons from high-energy gamma when ordinary collimator is utilized
- Triple-energy window technique enhances statistical noise
- Accuracy of head contour determination
- Adequate attenuation coefficient values if CT is utilized
- AC values compensating scatter and penetration between narrow and broad mu values

Existing phantom results from Yong Du et al (unpublished)
presented by Eric Frey – not yet available for distribution

# Some discussions from 12/08/2015 call

- Large ROI vs. tight ROI?
  - Large ROI does not allow separation of caudate, putamen, but accounts for PVE so better agreement between measured and true BR
  - Szabo, Frey: Tight ROI with separation of caudate putamen more clinically relevant
  - Hidehiro (email): ‘I agree that small ROIs are more informative, but the values can be more fluctuated, and sensitive to how reconstructed. Resolution recovery is one example. From academic point of view, I am interested in looking both data.’
- Do we have sufficient phantom data?
  - Frey: Yes, but possibly need to look at striatum size effects
- 3 levels of the claim. No correction, with correction, best corrections
  - Vija: should focus on including all corrections
  - Frey: Some centers not able to do the corrections. since looking at a ratio (SBR) some of the effects cancel out and may be able to get reasonable results without all corrections