QIBA SPECT BC

I-123 DAT SCAN: Acquisition and Reconstruction task force call

January 5, 2016

Profile writing

- To quote Mozley:

“Start by just writing something. It does not have to be good”

Profile writing: first attempt

- Attempt at filling in some of the sections for ‘Acquisition’
  - used the Tables in the QIBA FDG -PET/CT profile as a guideline.

- Hope to get couple of volunteers to continue with filling in the Tables for ‘Reconstruction’ section

Image Data Acquisition (section 3.2 in PET profile)

- Timing
- Subject positioning
- Scanning coverage and direction
- Scanner acquisition mode parameters
  - Imaging device
  - SPECT acquisition parameters
  - CT parameters

Scanner acquisition mode parameters

Parameter	Entity/Actor	Specification
Imaging device	Study sponsor	The acquisition device shall be selected to produce comparable results regardless of the scanner make and model.
		Camera: Multi detector SPECT or SPECT/CT cameras shall be used.
		Collimator: A collimator that satisfies the SPECT spatial resolution requirement of < 15 mm FWHM at 15 cm radius of rotation shall be used (add NEMA planar resolution or recon resolution in air). (Sufficient to accurately separately define Caudate and Putamen). LEHR and LEUHR and fan beam collimators typically meet this requirement. ME collimators, which reduce septal penetration may be insufficient in terms of the resolution requirement. If available, collimators designed specifically for I-123 brain SPECT shall be used. (Extended range LMEGP(Nuclear Fields), ELEGP(GE), multi Pinhole BIOSPECT)
Imaging device	Technologist	

- SPECT acquisition parameters

Parameter	Entity/Actor	Specification
SPECT Acq. Mode	Study sponsor	The key SPECT acquisition mode parameters shall be specified in a manner that is expected to produce comparable results regardless of the scanner make and model. The key parameters are:
		Rotational radius: shall be fixed at 11 – 15 cm (circular orbit) or smallest possible?
		Matrix and pixel size: A matrix size and zoom factor that gives a pixel size of one-third to one-half the expected spatial resolution shall be used. Typically, a 128 x 128 matrix and pixel size of 3.5 – 4.5 mm.
		Angular sampling: 360 degree coverage of the head with angular sampling of not less than 120 views shall be used (<= 3 degree increments). Step-and-shoot is typically used, but continuous mode can be used to provide shorter total scan time.
		Total counts: The scan time shall be adjusted to obtain > 1.5 million total counts detected in the photopeak window. Typically, this requires a 25 – 45 min scan.
		Energy windows: The photopeak window shall be set at 150 keV +- 10% (143 – 175 keV). If triple energy-window based scatter correction is to be used, two additional narrow windows (3%, 7% ?) adjacent to the photopeak shall be used.

SPECT Acquisition Parameters

- These parameters are based on past guidelines and/or manufacturer prescribing information. Example:

  – Experimental studies with a striatal phantom suggest that optimal images are obtained with matrix size and zoom factors selected to give a pixel size of 3.5 to 4.5 mm. Collect a minimum of 1.5 million counts for optimal images. (from DaTscan prescribing information)

  – A 128 x128 matrix is recommended. Experimental studies with a striatal phantom suggest that optimal images are obtained when the selected matrix size and zoom factors give a pixel size of 3.5–4.5 mm. Slices should be 1 pixel thick. (from SNM practice guidelines)

- Neither of above provide references for the quoted phantom studies
  - Were these recommendations based on past studies done without correction for scatter etc?
  - May need QIBA sponsored sub project to investigate

- CT Acquisition

Parameter	Entity/Actor	Specification
CT Acquisition Mode	**Study Sponsor**	The key CT acquisition mode parameters (kVp, mAs, pitch, and collimation) shall be specified in a manner that is expected to produce comparable results regardless of the scanner make and model and with the lowest radiation doses consistent for the role of the CT scan: correction for attenuation and for localization. If diagnostic or anatomical localization CT images are not needed, then the CT acquisition mode shall utilize the protocol that delivers the lowest possible amount of radiation dose to the subject (e.g. an ultra-low low dose protocol) that retains the quantitative accuracy of corrections for attenuation.
CT Acquisition Mode	**Technologist**	The key CT acquisition mode parameters (kVp, mAs, pitch, and collimation) shall be set as specified by study protocol and used consistently for all subject scans.

- CT Acquisition

Parameter	Entity/Actor	Specification
CT Technique: Protocol Design	**Technologist / Physician / Medical Physicist**	A team comprising a Technologist / Physician / Medical Physicist shall ensure that CT techniques protocols are designed such that dose exposure is the lowest radiation dose necessary to achieve the objective in children and adults. Protocols defined by Image Gently and Image Wisely should be used where feasible. The protocol shall be recorded and documented.
CT Technique: Dose Exposure	**Technologist**	The Technologist shall ensure that CT dose exposure is the lowest radiation dose necessary to achieve the diagnostic objective in children and adults.

Moving on to Reconstruction

- Latest paper accepted to EJNMMI (manuscript provided by Hidehiro Iida). Details to be discussed at a future call?

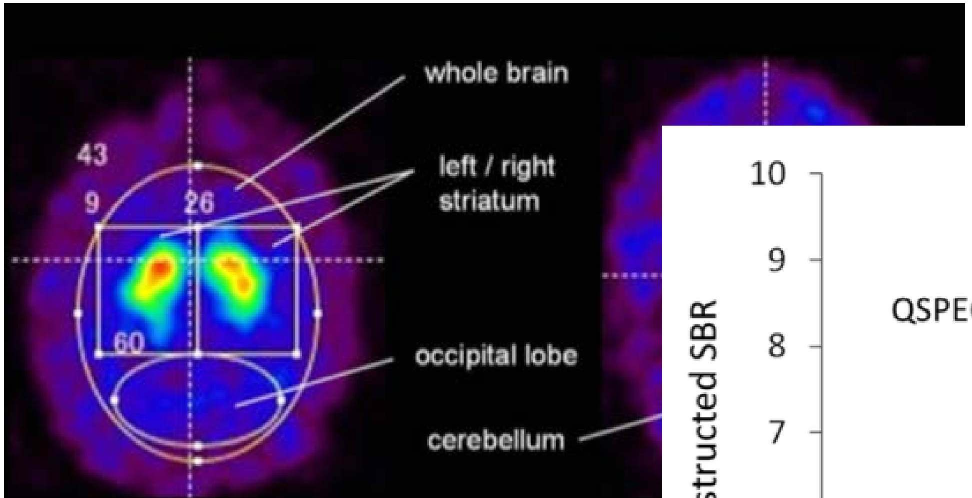
Reduction of camera specific variability in [123I]FP-CIT SPECT outcome measures by image reconstruction optimized for multi-site settings: impact on age dependence of the specific binding ratio in the ENC-DAT database of healthy controls

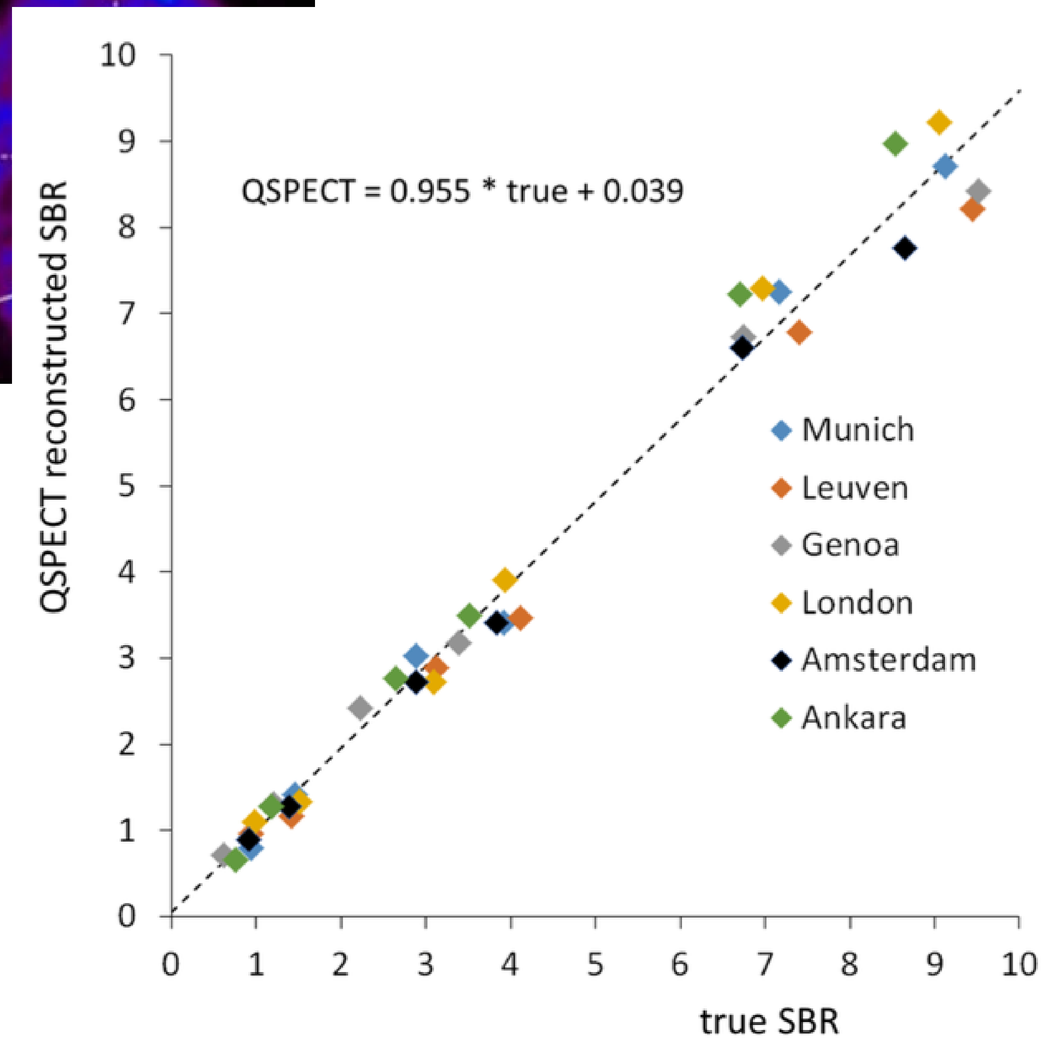
Ralph Buchert1* (Ralph.buchert@charite.de), Andreas Kluge2* (Kluge@abx-cro.com), Livia Tossici-Bolt3 (livia.bolt@uhs.nhs.uk), John Dickson4 (john.dickson@uclh.nhs.uk), Marcus Bronzel2 (bronzel@abx-cro.com), Catharina Lange1 (catharina.lange@charite.de), Susanne Asenbaum5 (susanne.asenbaum@meduniwien.ac.at), Jan Booij6 (j.booij@amc.uva.nl), Özlem L. Kapucu7 (kapucu@gazi.edu.tr), Claus Svarer8 (csvarer@nru.dk), Pierre-Malick Koulibaly9 (koulibal@unice.fr), Flavio Nobili10 (flaviomariano.nobili@hsanmartino.it), Marco Pagani11 (marco.pagani@istc.cnr.it), Osama Sabri12 (osama.sabri@medizin.uni-leipzig.de), Terez Sera13 (sera.terez@med.u-szeged.hu), Klaus Tatsch14 (Klaus.Tatsch@klinikum-karlsruhe.de), Thierry Vander Borght15 (thierry.vanderborght@uclouvain.be), Koen Van Laere16 (koen.vanlaere@uz.kuleuven.ac.be), Andrea Varrone17 (andrea.varrone@ki.se), Hidehiro Iida18 (iida@ri.ncvc.go.jp)

New EJNMMI paper …

- QSPECT software package which provides fully automated detection of the outer contour of the head, camera specific correction for scatter and septal penetration by transmission-dependent convolution subtraction, iterative OSEM reconstruction including attenuation correction, and camera specific calibration to kBq/ml.

New EJNMMI paper





‘The true SBR was reproduced with an accuracy of ± 5% in almost all cases.’

Moving on to Reconstruction

✓ Attenuation Correction
  – Constant mu map
  – CT-based

✓ Scatter/Penetration Correction
  – Triple Energy Window
  – Transmission Dependent Convolution Subtraction

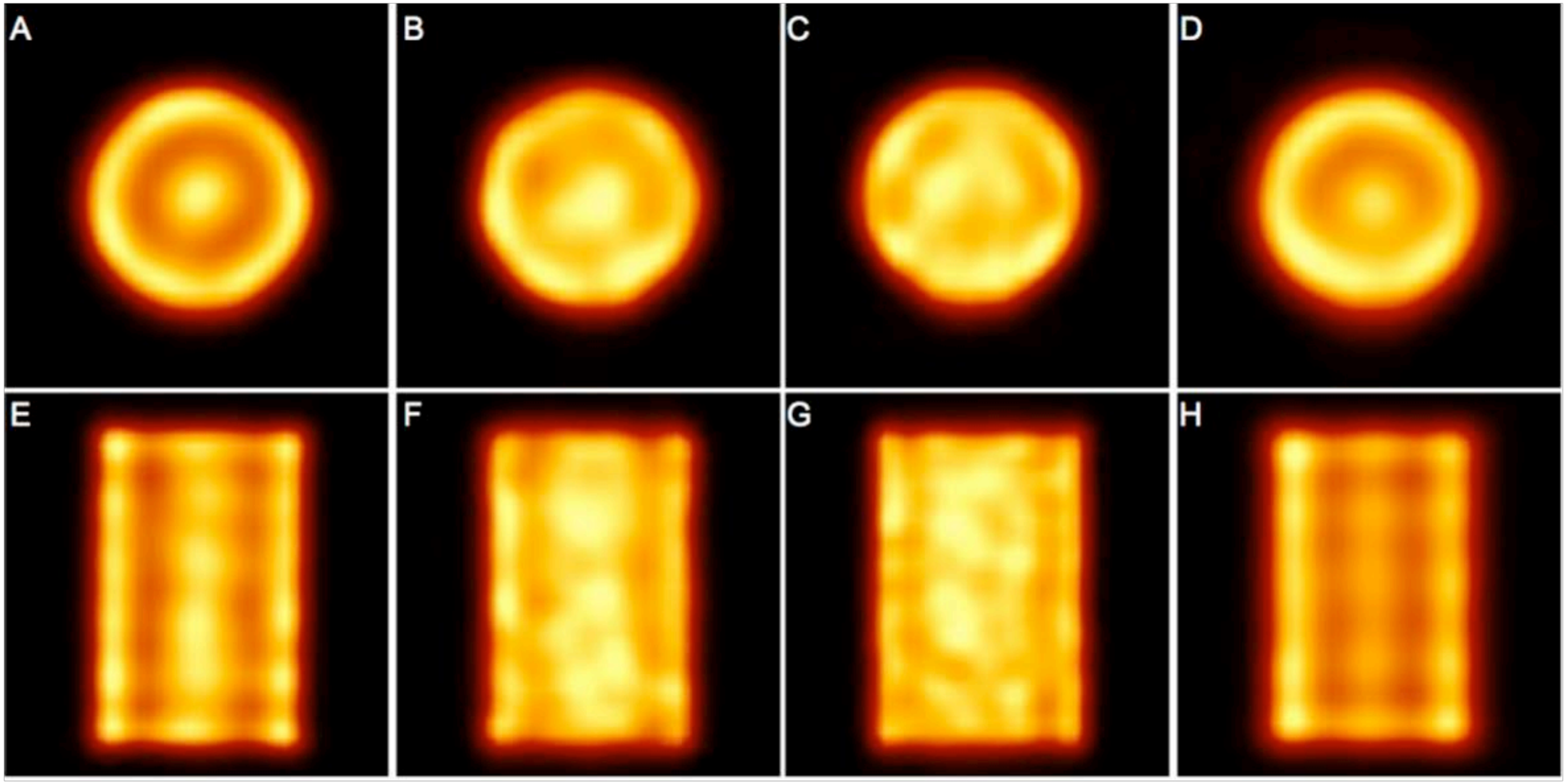
?? Resolution Recovery

Resolution recovery

- The distance dependent 3D collimator-detector response (CDR) can be included in the reconstruction model
  - Available with most SPECT/CT commercial software
- Pros
  - Significantly better contrast recovery and quantification for small structures
- Cons
  - Reconstruction artifacts
  - Increase in computation time

Artifacts from Resolution Recovery

Phantom study with Tc-99m: Seret A et al. Quantitative capabilities of four state-of-the-art SPECT-CT cameras. EJNMMI Res. 2012



Transverse and coronal slices of the M phantom obtained after 24 iterations. (A, E) Philips Brightview XCT and Astonish. (B, F) General Electric Discovery NM/CT 670 and Evolution for Bone. (C, G) General Electric Hawkeye 4 and Evolution for Bone. (D, H) Siemens Symbia T6 and Flash3D. All are reconstructions with eight subsets. Hot-iron color scale from 0% to 110% of slice maximum.

Phantom study with Tc-99m: Seret A et al. Quantitative capabilities of four state-of-the-art SPECT-CT cameras.

- ‘These artifacts were not observed when the data were reconstructed with FBP or with OSEM including attenuation and scatter corrections but not resolution recovery.’

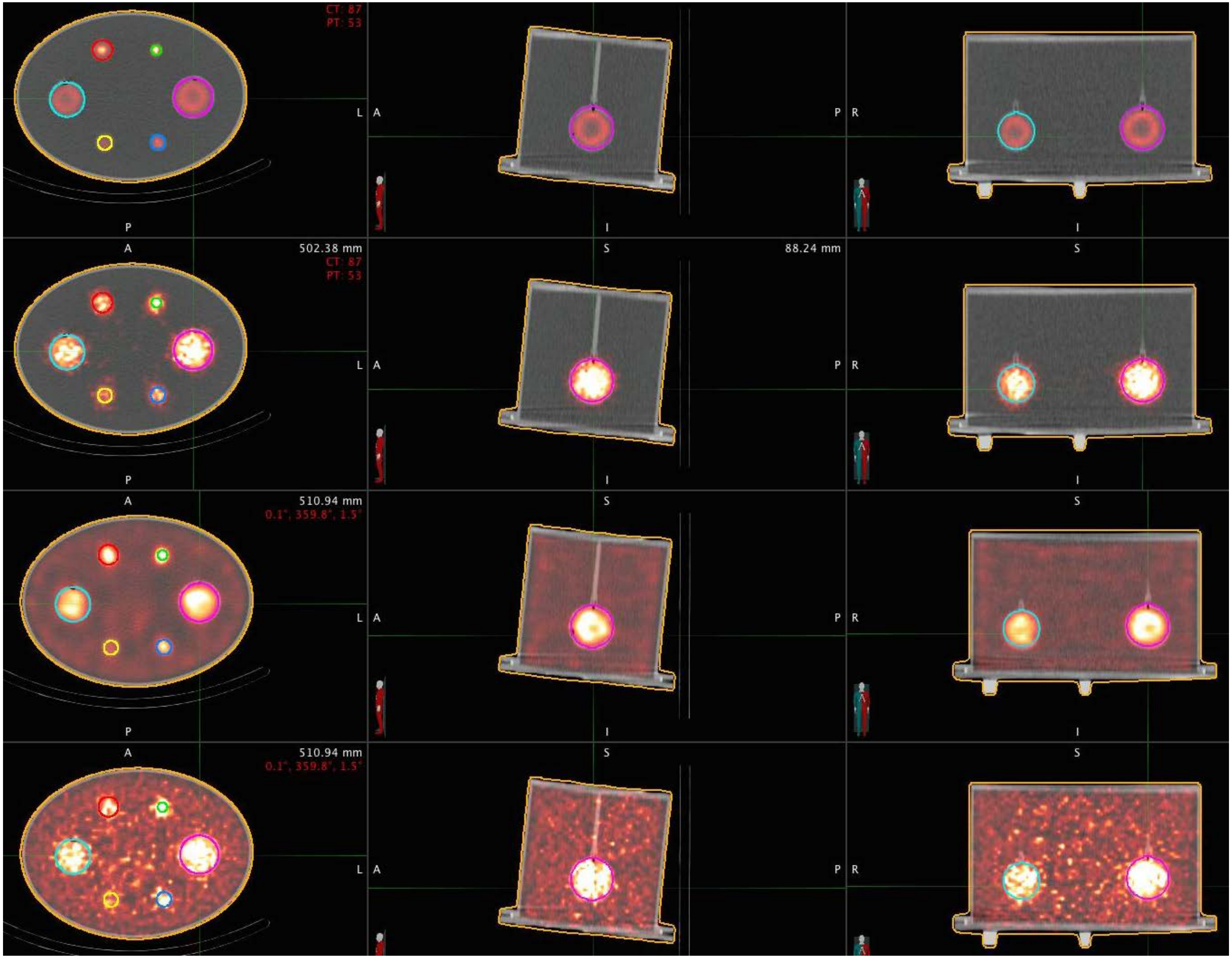
Edge artifacts in I-131 SPECT: Dewaraja (unpublished)

Phantom with no bkg. OS-EM with CDR

Phantom with no bkg. OS-EM without CDR

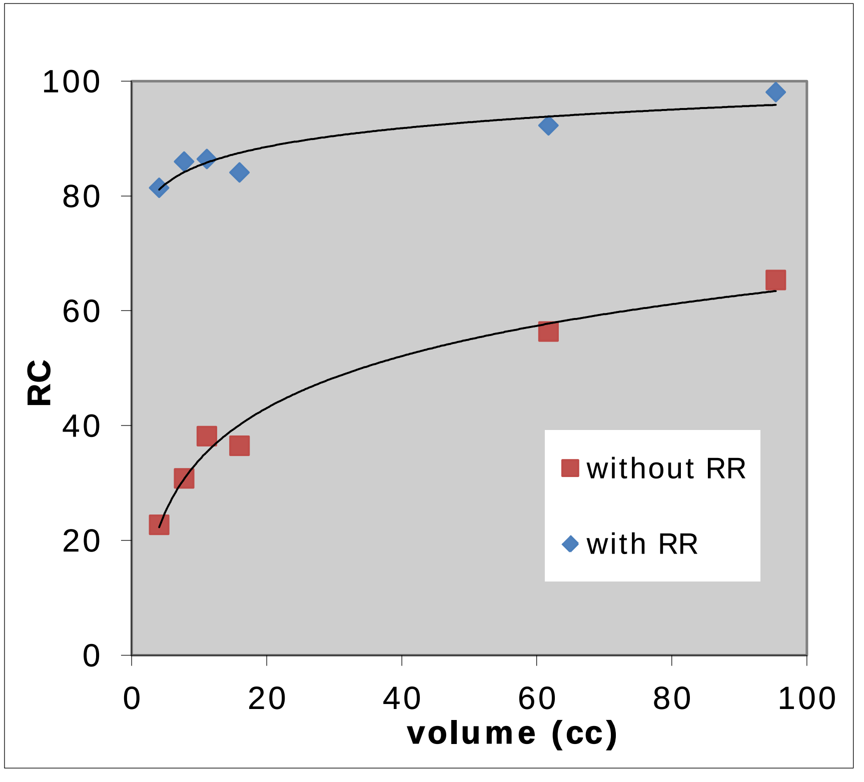
Phantom with bkg. OS-EM with CDR

Phantom with bkg. OS-EM without CDR

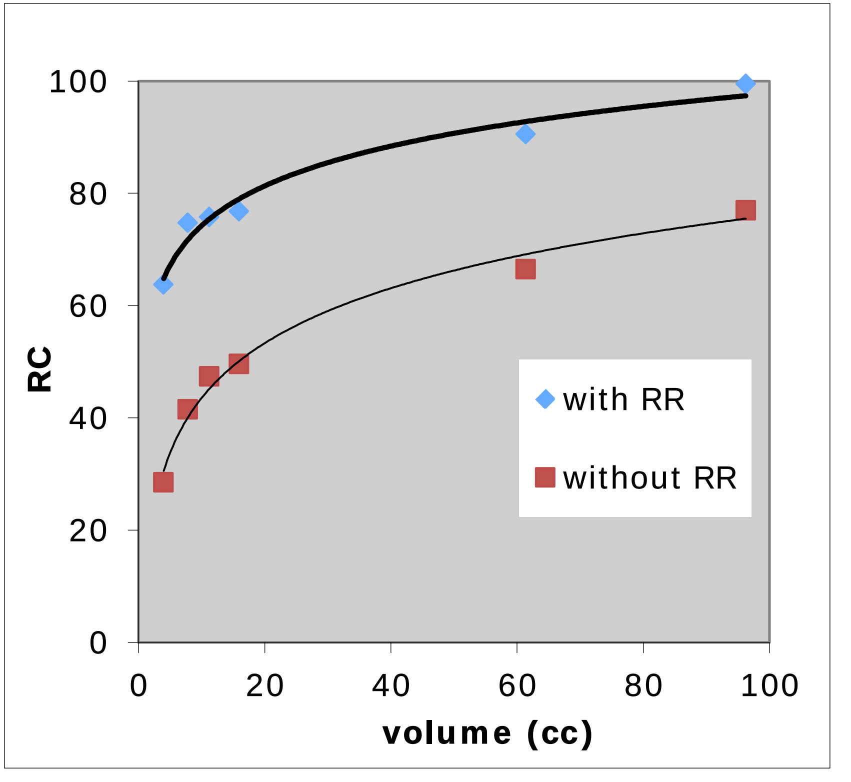


I-131 SPECT: Improved Activity Recovery with CDR Modeling. Dewaraja (unpublished)

Phantom with no bkg activity



Phantom with bkg activity



RC = recovery coefficient = SPECT estimated activity / True activity

Resolution Recovery

- Any I-123 DAT scan comparisons with and without (commercially available) resolution recovery?
  - Possibly Eric Frey, Young Du unpublished results?

Profile writing: Image Reconstruction. Example FDG PET/CT

Parameter	Entity/Actor	Specification
PET image reconstruction	Study Sponsor	The key PET reconstruction parameters (algorithm, iterations, smoothing, field of view, voxel size) shall be specified in a manner that is expected to produce comparable results regardless of the scanner make and model.
		The key PET image reconstruction parameters shall be specified according to pre-determined harmonization parameters.
PET image reconstruction	Technologist	The key PET reconstruction parameters (algorithm, iterations, smoothing, field of view, voxel size) shall be followed and set as specified in order to produce comparable results regardless of the scanner make and model.
PET Matrix/Voxel size	Technologist	The Technologist shall perform the image reconstruction such that the matrix, slice thickness, and reconstruction zoom shall yield a voxel size of < 5mm (strongly prefer 3 – 4 mm) in all three dimensions for whole body imaging [for dedicated head and neck imaging, smaller ($\leq$ 3mm) voxels are preferable], although not necessarily isotropic. The final size shall not achieved by re-binning, etc., of the reconstructed images.
Correction factors	Technologist	All quantitative corrections shall be applied during the image reconstruction process. These include attenuation, scatter, randoms, dead-time, and efficiency normalizations.
Calibration factors	Scanner	All necessary calibration factors needed to output PET images in units of Bq/ml shall be automatically applied during the image reconstruction process.

From QIBA Profile Template

- (COMMENT) Try to focus Reconstruction requirements on the characteristics of the data that comes out of the Reconstruction (i.e. the results) rather than on the procedure for producing those results. Constraining the procedure can unnecessarily impede innovative methods or technologies that would meet or exceed the needed performance

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.

References related to Acquisition & Reconstruction contd.

11. Du Y, Tsui BM, Frey EC. Model-based compensation for quantitative 123I brain SPECT imaging. Phys Med Biol. 2006 Mar 7;51(5):1269-82.
12. Buchert R, Kluge A, Tossici-Bolt L et al. Reduction of camera specific variability in 123I FP-CIT SPECT outcome measures by image reconstruction optimized for multi-site settings:impact on age dependence of the specific binding ratio in the ENC-DAT database of healthy controls. Accepted for publication in EJNMMI 2016.
13. Seret A, Nguyen D, Bernard C. Quantitative capabilities of four state-of-the-art SPECT-CT cameras. EJNMMI Res. 2012 Aug 27;2(1):45.