BIR - 2nd Annual SPECT/CT Symposium: Current Status & Future Directions of SPECT/CT Imaging
25th February 2013
London

Methodological aspects of current SPECT/CT practice

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NHS Foundation Trust

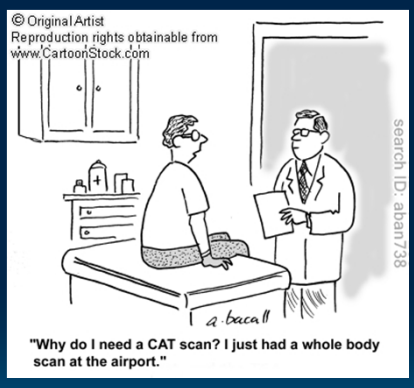
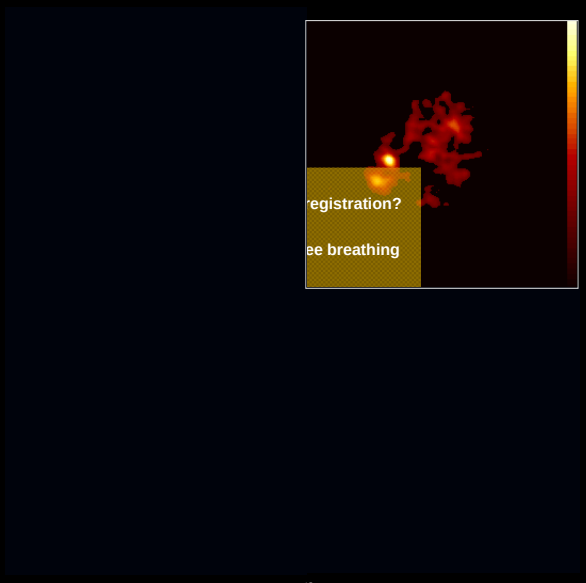


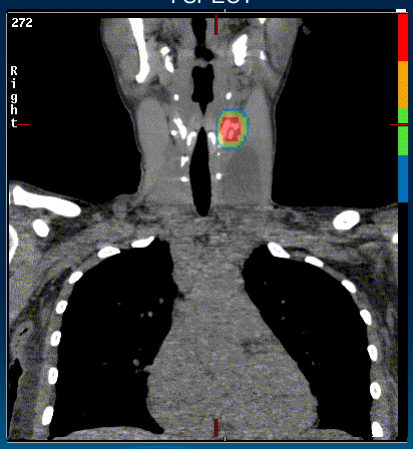
Image fusion: Software



Registration of X-ray CT images (top left) with ^{18}FDG PET images (top right) in lung tumour.
MRCCU, Hammersmith Hospital

SPECT/CT – Driven by anatomical localisation

^{131}I SPECT



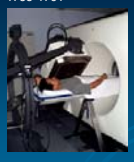
Development of SPECT/CT

1989

1989: Fleming JS. A technique for using CT images in attenuation correction and quantification in SPECT. Nucl Med Commun. 1989 Feb;10(2):83-97.

1994

1994: UCSF Blankespoor SC, Hasegawa BH et al
Development of an emissiontransmission CT system combining x-ray CT and SPECT. IEEE Nuclear Science Symposium and Medical Imaging Conference 4, 1758-1761



1999

1998: Townsend DW et al
The SMART scanner: a combined PET/CT tomograph for clinical oncology. IEEE Nuclear Science Symposium and Medical Imaging Conference 2, 1170-1174

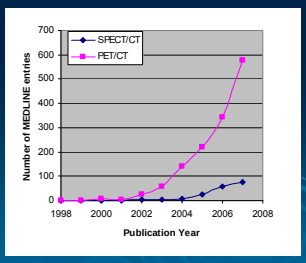
1999: First commercial SPECT/CT, GE Hawkeye

2005

2000: First commercial PET/CT, CTI/Siemens

2009

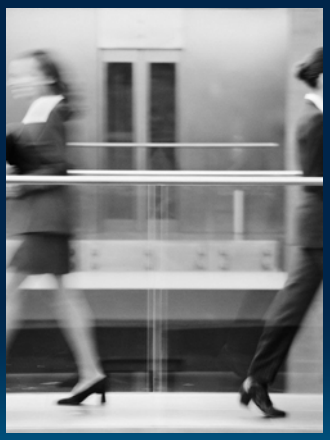
2005 Multi-Detector CT in SPECT/CT, Philips Precedence



PET/CT V SPECT/CT as imaging modalities

PET/CT:

- PET introduced early 1970s
- Maintained a culture for quantification (AC always possible)
- Remained a research tool (limited by cost/availability)
- Rapid expansion in 2000s (development of PET/CT)
- CT granted PET/CT foremost cost-effectiveness (reduced AC scan time) with the added value of localisation

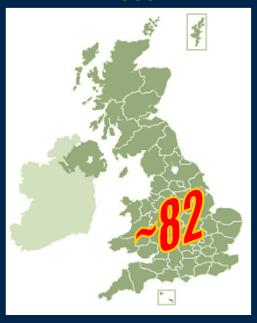


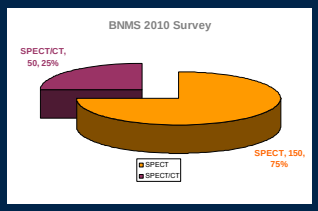
SPECT/CT:

- SPECT followed PET development
- Weak culture for quantification (non-uniform AC only practical recently)
- Quickly developed into a clinical diagnostic tool (low cost/ good availability)
- No recent expansion as modality
- CT grants SPECT/CT foremost anatomical localisation (no practical benefit to AC as CTAC usually requires extra acquisition time unlike radionuclide AC)

Trends of SPECT/CT utilisation in the UK

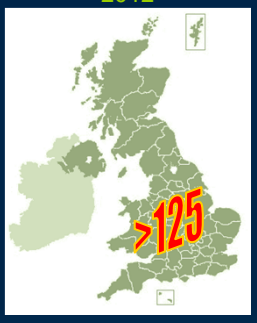
2009





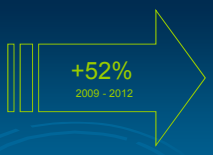
Responded to specific question 111
Responders 139
Total surveyed 220
http://bnms.org.uk

2012



Breakdown by CT component:

- 1-slice = 48
- 2-slice = 9
- 4-slice = 15
- 6-slice = 4
- 16-slice = 6

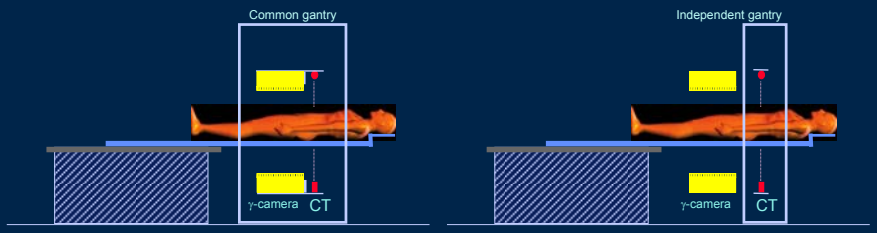


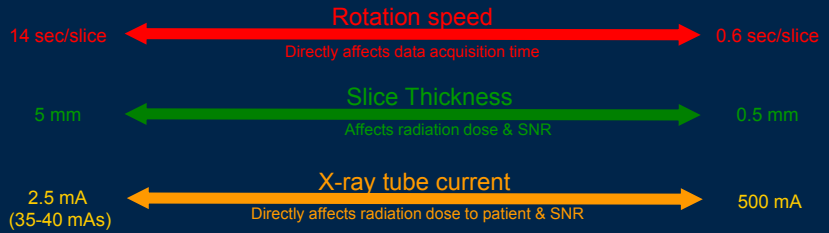
Breakdown by CT component:

- 1-slice = >48
- 2-slice = 27
- 4-slice = >15
- 6-slice = 7
- 16-slice = 16
- Cone-Beam etc = 12

Unofficial data – based on informal communication with manufacturers. In some cases, systems scheduled to be installed in the near future have been included.

Commercial SPECT/CT Systems



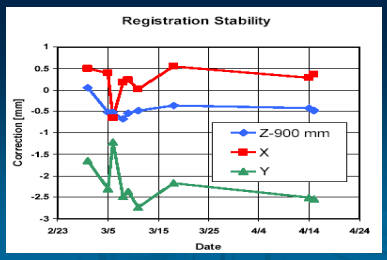


SPECT/CT Spatial Registration

CT

multi-point source phantom

SPECT



+Radiation Exposure in Multi-Modality Imaging

Radiation Exposure ←→ Image Quality

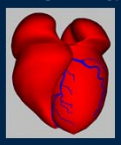
L-CT Localisation ~ 3 mSv

CTAC
"Attenuation Correction"
~1 ± 0.5 mSv

D-CT
Diagnostic
'one-stop shop'
1 - 10 mSv

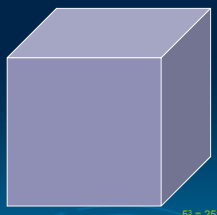
Required CT quality for SPECT/CT ?

- *Multi-detector CT: How many slices are required?*



WP Segars et al. A realistic spline-based dynamic heart phantom. Nuclear Science, IEEE Transactions, 1999

- *CT Slice Thickness V SPECT Voxel Size*



Required CT quality for SPECT/CT ?

Dependency from Patient Management algorithm?

Appl Radiol, 40, Number 05, May 2011

Am Fam Physician. 2006 Mar 15;73(6):1014-1022.

Dose Saving Schemes

concept of angular-longitudinal dose modulation

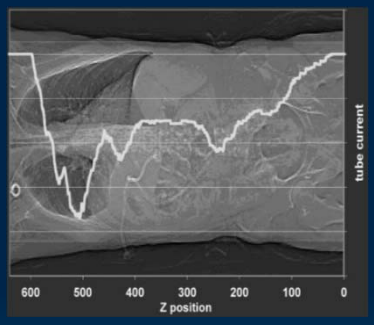


Table 8
Effective Tube Current–Time Product Decreases Relative to a Constant Value Used for All Adult Patients

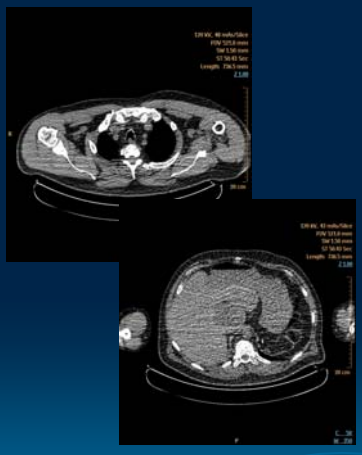
Category	Decrease (%)*
All patients	18.5
Slim patients	44.9
Large patients	3.1

*Indicates decrease in effective tube current–time product with use of the described AEC system, compared with a single effective tube current–time product used for all adult patients.

CT Dose Reduction and Dose Management Tools: Overview of Available Options
CH McCollough, MR Bruesewitz, JM Kofler - Radiographics, 2006, 26:503-512

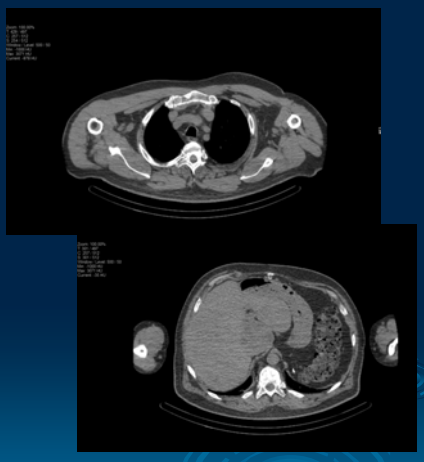
Case study: Dose & SNR

- **System A**



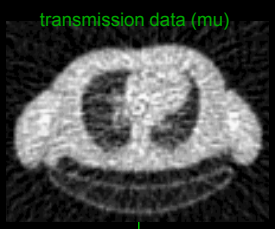
*Visit 2 DLP = 323 mGy*cm*

- **System B**

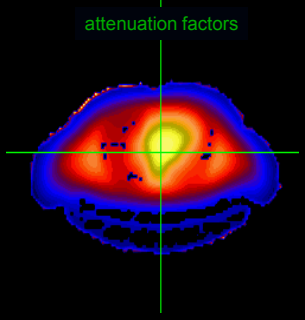


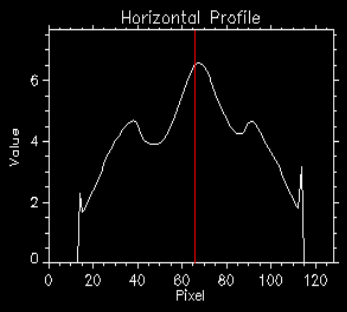
*Visit 3 DLP = 702 mGy*cm*

Photon Attenuation



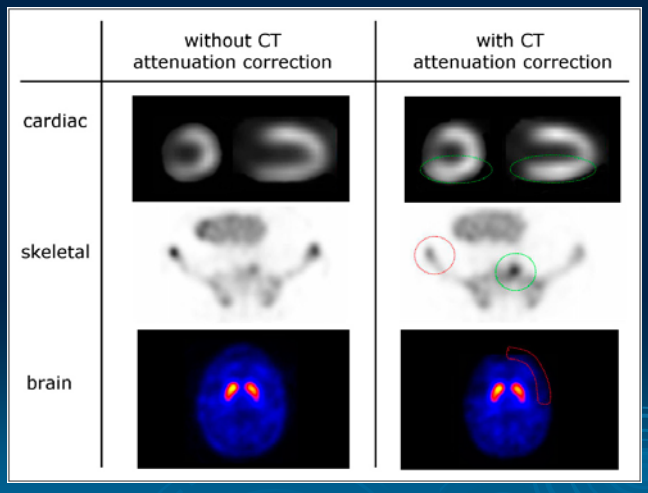
^{99m}Tc Attenuation Correction Factors





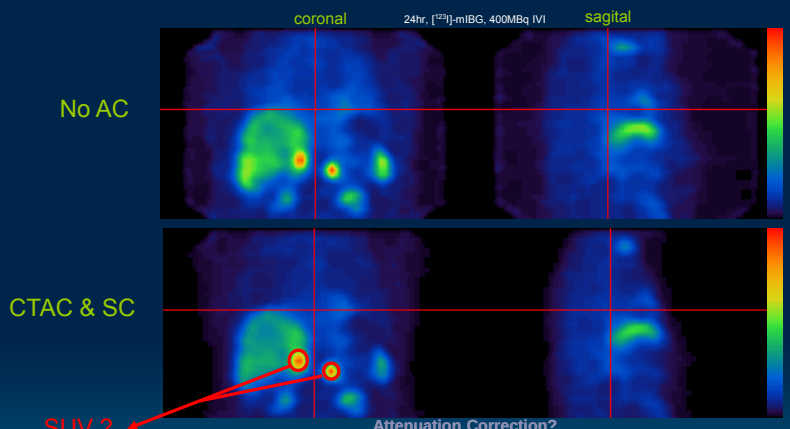
*D Bailey, Transmission scanning in emission tomography ." *J Nucl Med* 25(7): 774-787

CT-Based Attenuation Correction



Buck AK et al, SPECT/CT, J Nucl Med. 2008 Aug;49(8):1305-19

Attenuation & Scatter Correction



SUV ?
progression?
volume?

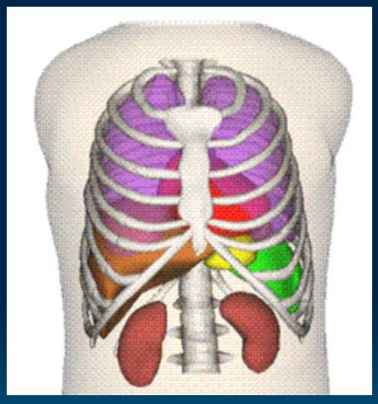
Attenuation Correction?

	PET	SPECT
FBP		
Iterative (EM)		

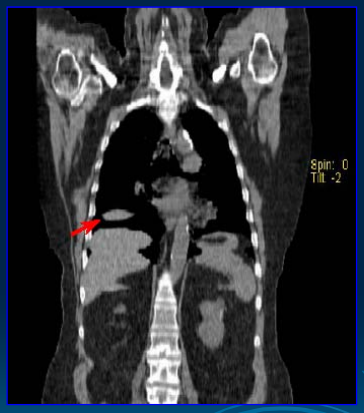
SPECT is quantitative!

Challenges:
Patient Motion

Respiratory motion in CT



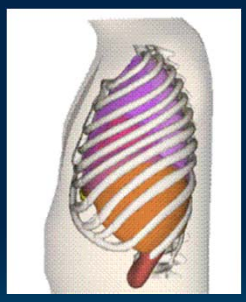
Respiratory Motion with the 4D NCAT
WP Segars et al. A realistic spline-based dynamic heart phantom. Nuclear Science, IEEE Transactions, 1999



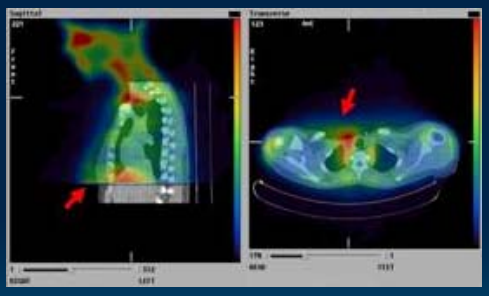
"Floating liver" artefact – breathing during helical CT acquisition

Respiratory motion in SPECT/CT

"Fast" - "Slow" CT component for AC?



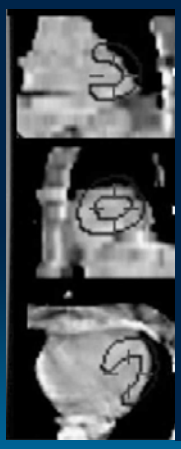
Respiratory Motion with the 4D NCAT
WP Segars et al. A realistic spline-based dynamic heart phantom. Nuclear Science, IEEE Transactions, 1999



Fusion display of CT and 131I-mIBG SPECT (free breathing

SPECT/CT mis-registration

Myocardial boundary from SPECT super-imposed on CTAC



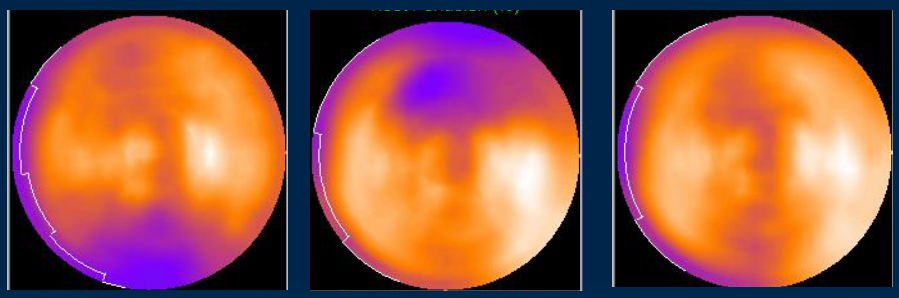
- Necessity for data QC!!!

Goetze S, Brown TL, Lavely WC, Zhang Z, Bengel FM., Attenuation correction in myocardial perfusion SPECT/CT: effects of misregistration and value of reregistration. J Nucl Med. 2007 Jul;48(7):1090-5.

SPECT/CT mis-registration

Effect of mis-registration in MPI

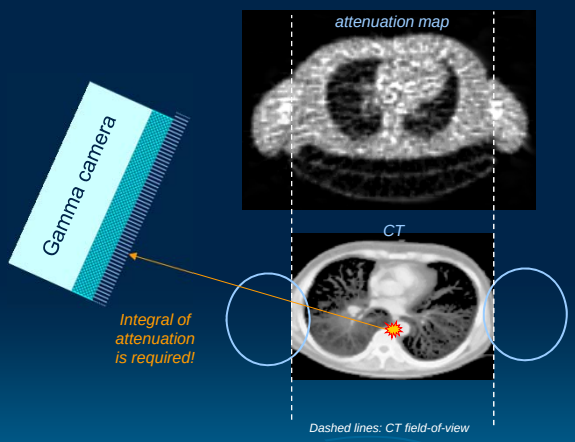
bull's eye plots



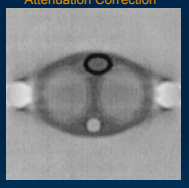
No correction | Attenuation correction only | Registration correction and attenuation correction

Data courtesy of Prof Richard Lawson, Manchester Royal Infirmary

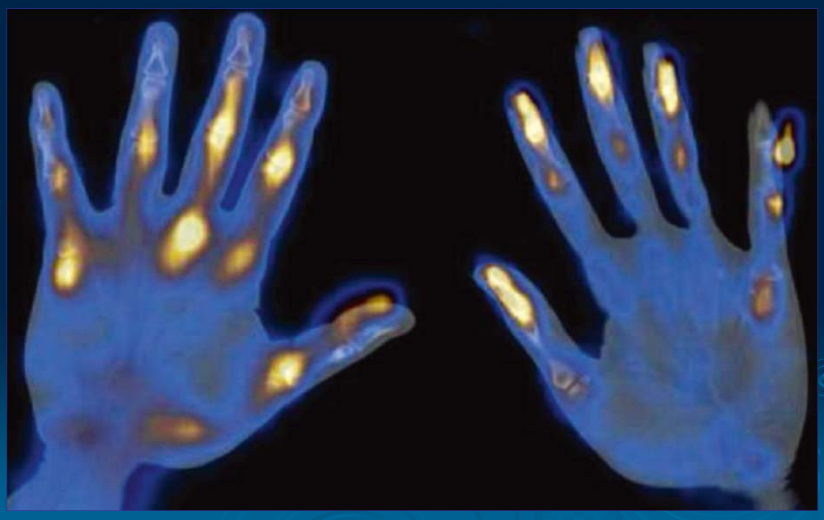
Truncation Artefacts



Simulated Emission Data with Truncated CT-based Attenuation Correction



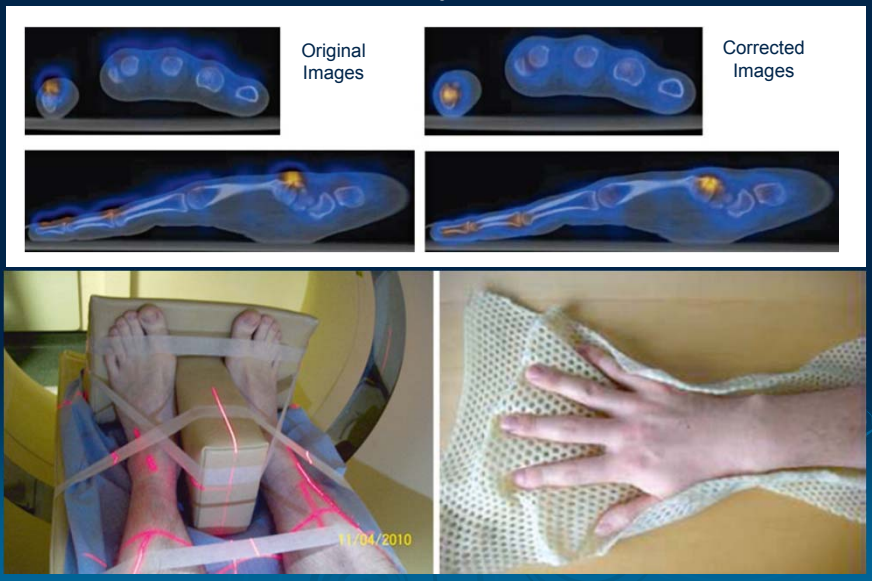
Patient Motion



^{99m}Tc-MDP SPECT/CT images of the wrist

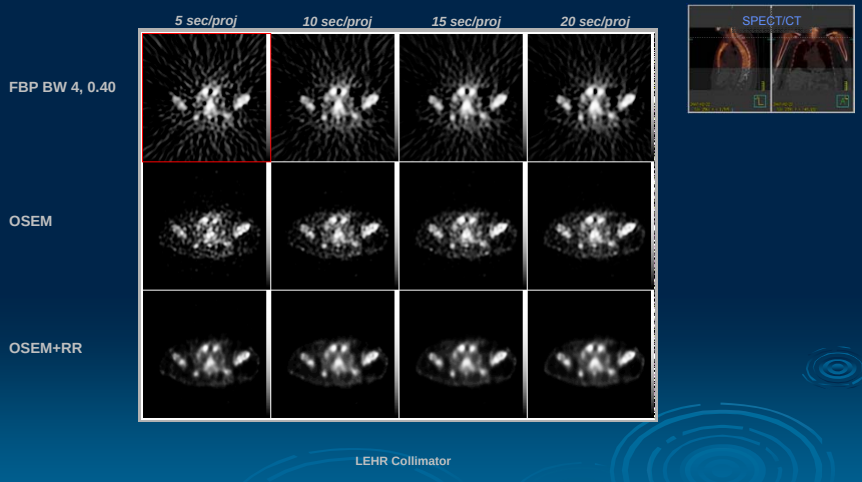
Patient Motion

^{99m}Tc-MDP SPECT/CT images of the wrist

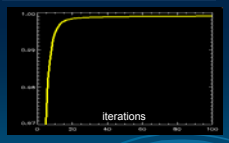


Accelerated Data Acquisition – "Resolution Recovery" + OSEM

^{99m}Tc-MDP



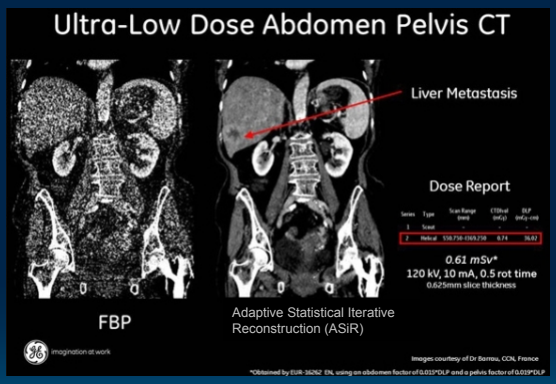
Non-Uniform Convergence of EM



- convergence is tracer distribution dependent
- optimisation required
- bias versus noise compromise
- perhaps best to over-iterate then filter to control noise
- Multi-centre experience: NMSWQ(IPEM) / ARSAC Resolution Recovery audit http://nmsqg.org/

Re-drawn from J Nuyts, IEEE Nuclear Science Symposium and Medical Imaging Conference,2000

Iterative CT Reconstruction



Source: Diagnostic Imaging - http://www.diagnosticimaging.com/ct/content/article/113619/1969393

Hybrid SPECT/CT and PET/CT are well placed for early implementation of iterative CT!

Summary

- Rapid growth of SPECT/CT (with diagnostic capabilities CT)
  - +52 % (2009-2012)
- Challenges:
  - Justification – Resources
  - Additional Radiation Dose
  - Adequate Image Quality for CT?
  - Where does SPECT/CT fit into Patient Management algorithm?
    - Is this the right point to re-evaluate?
  - Staff training / Professional competencies
  - Technical aspects
    - Patient Motion
    - Availability of fused images / Outreach
- Opportunities:
  - Improved localisation accuracy in Nuclear Medicine
  - Widely accessible equipment base
  - Range of established (and new) radiopharmaceuticals
  - Body of experience leading to clearer patterns of utilisation would be NICE
  - Technical aspects:
    - Accelerated Acquisition (SPECT)
    - Dose saving schemes & Iterative reconstruction (CT)
    - Data corrections e.g. CTAC & Resolution Recovery enabling SUV quantification

Thank you!