Evolution of SPECT from Qualitative to Quantitative imaging

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Summary

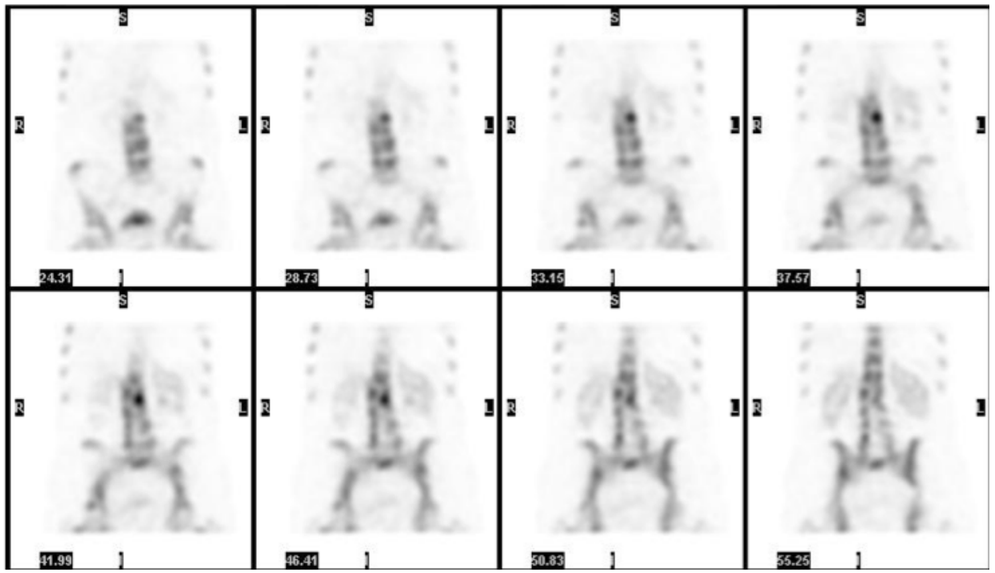
The road to quantitative SPECT

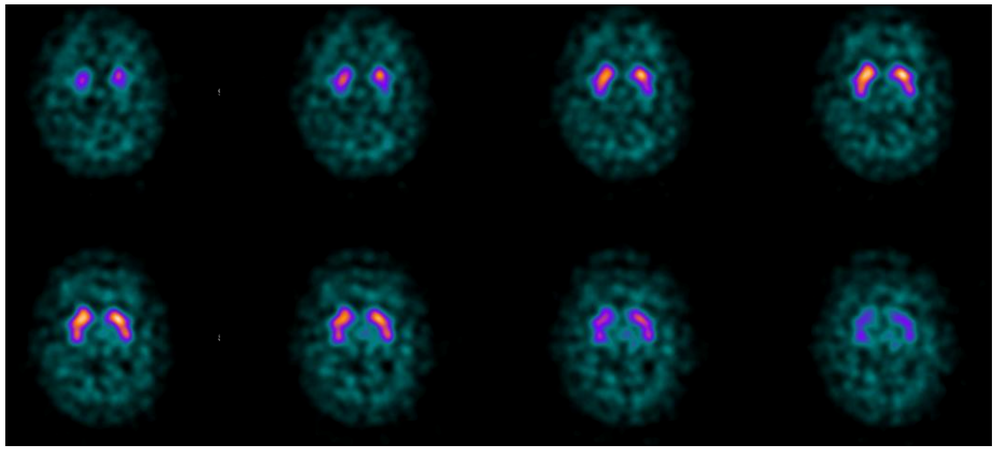
- Introduction to SPECT
- Equipment evolution
- Software evolution
- New applications and the need for quantitative SPECT

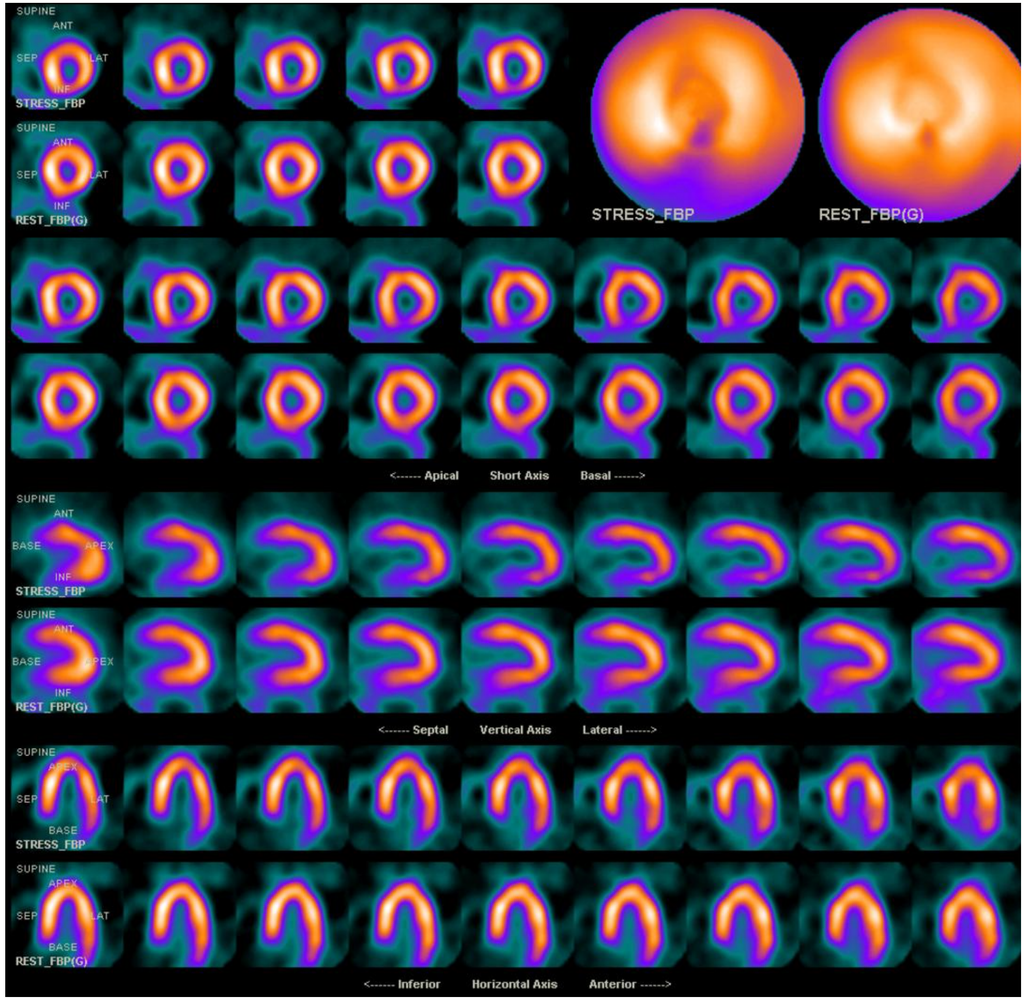
An Introduction to SPECT

SPECT: Single Photon Emission Computer Tomography

A Nuclear Medicine Technique







SPECT

Performed on a gamma camera

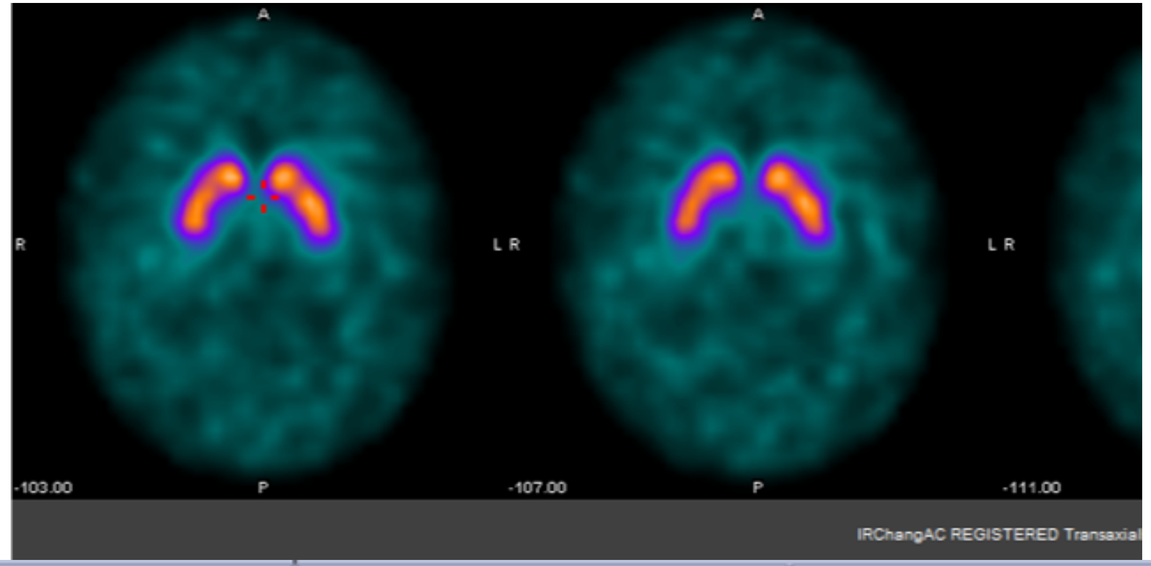
- Typically two rotating detectors acquiring data for 20-30 minute
- Use of radiopharmaceutical to image in-vivo physiology
  - Bone turnover
  - Myocardial perfusion
  - Dopamine Transporter
  - …….

Image Courtesy of Siemens Healthineers

But I’ve seen quantification in SPECT, so what’s new?

Semi-quantification

- Image interpretation mostly based on image appearance
- Some ‘semi-quantification’ performed i.e. relative to a region within the image and/or database
  - e.g. specific tracer uptake in striata compared to non-specific uptake elsewhere

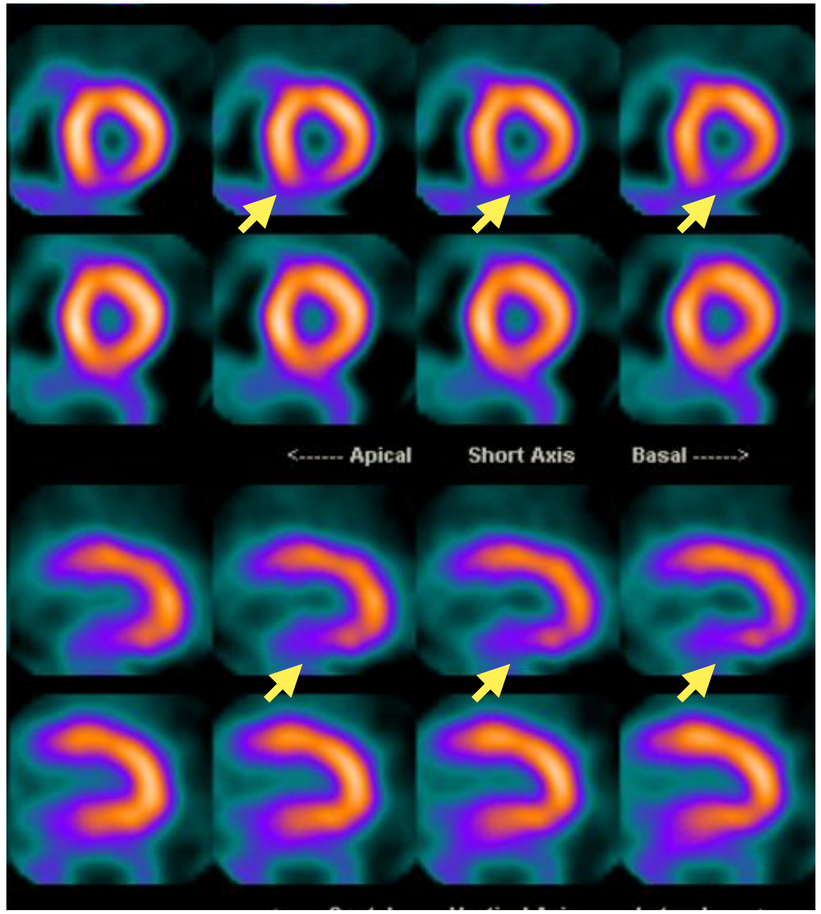


	Striatum Right SBR	Striatum Left SBR
Measured	+3.21	+3.29
Mean (±1 SD)	+3.66 (±0.40)	+3.73 (±0.42)
Deviation	-12%	-12%
Z-Score	-1.11	-1.03

Equipment Evolution

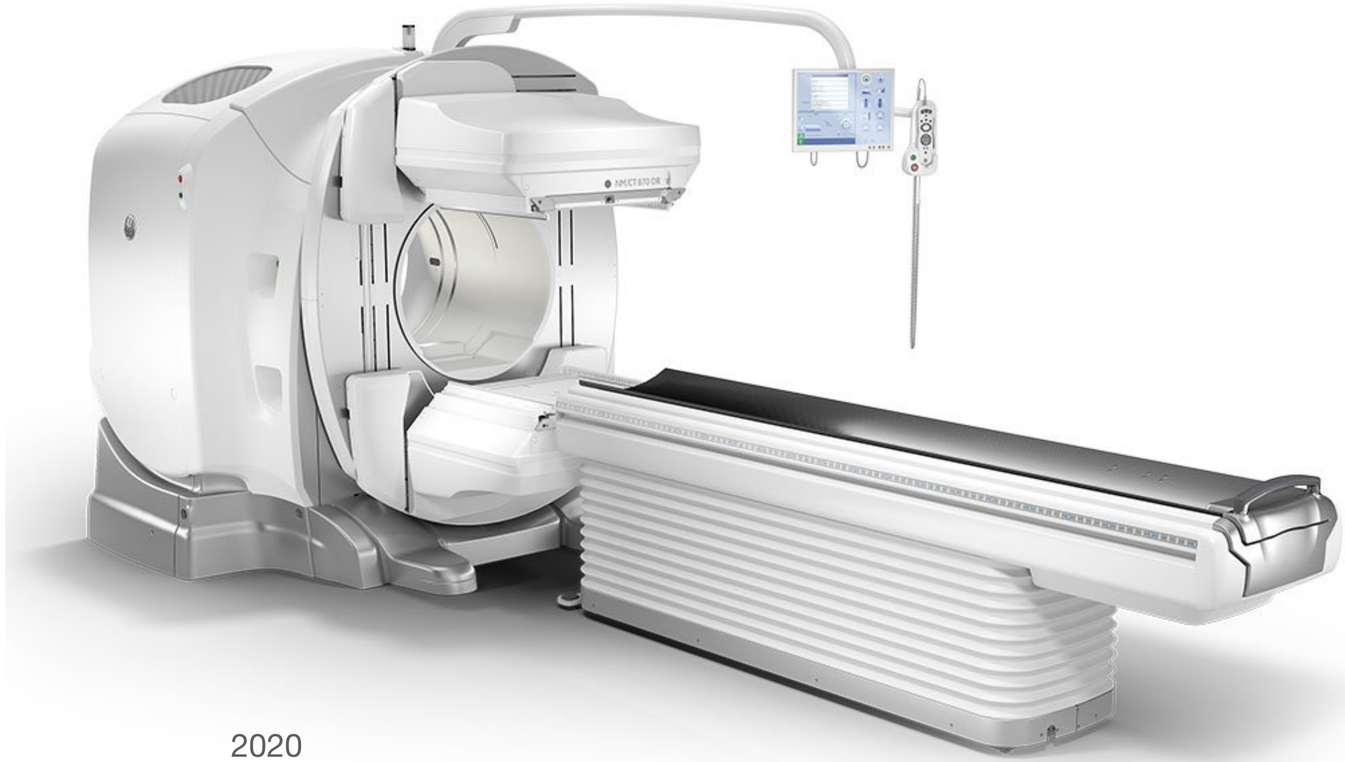
Attenuation correction

- Cardiac SPECT.
- Looks at regional blood flow homogeneity in myocardium
- Big patients show inhomogeneities because of photon attenuation
- Attenuation correction with transmission sources
- Attenuation correction with low dose CT



Evolution of SPECT/CT

1999 - Before PET/CT
Slow rotation
Low Tube Current
Thick 1cm slice



2020
Contemporary 16 slice CT

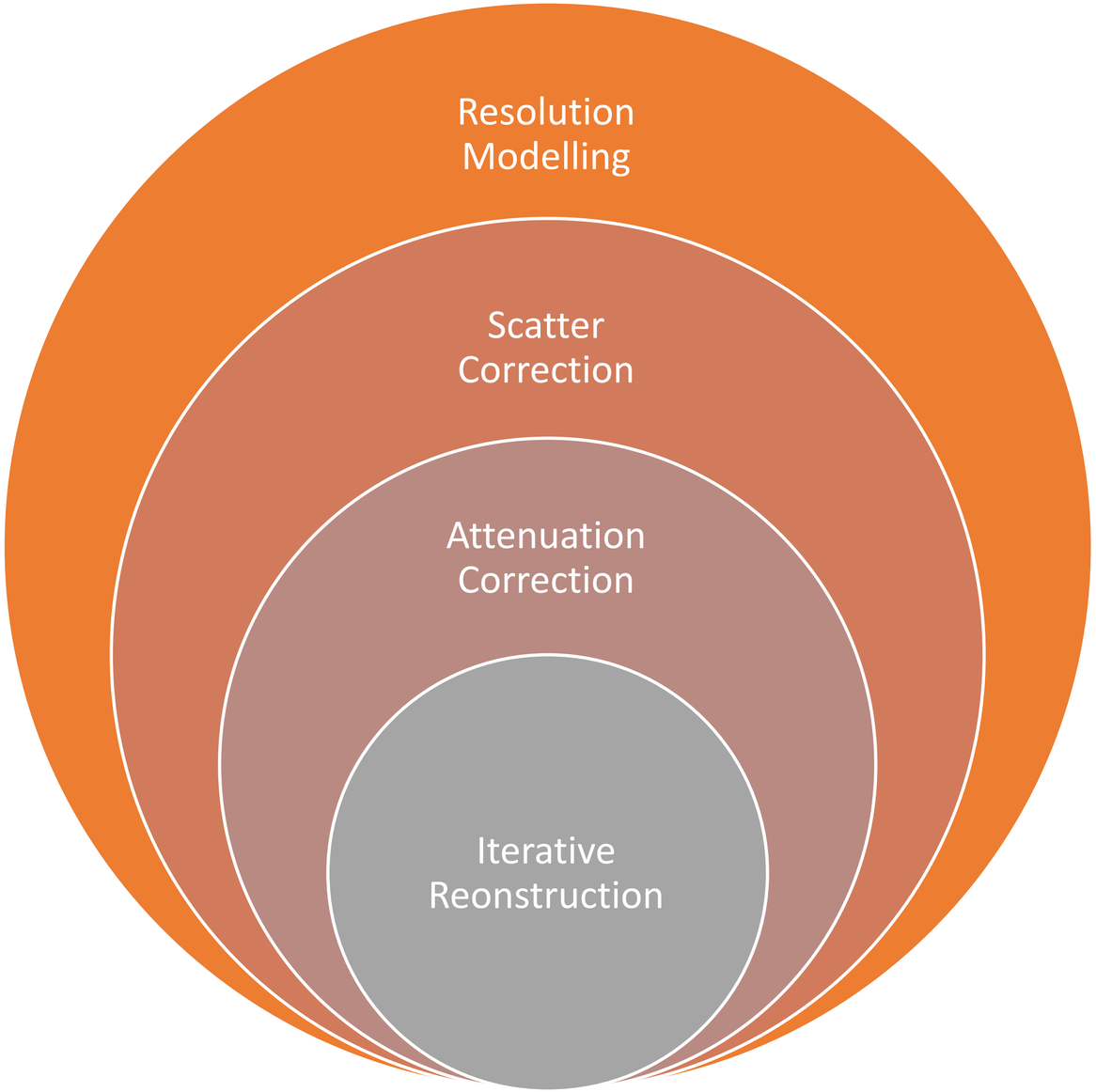
Images courtesy of GE Healthcare

Semiconductor (CZT) Technology

- Smaller detector = more innovative designs
- Energy and spatial resolution improvements
- Increased sensitivity
- More later ……

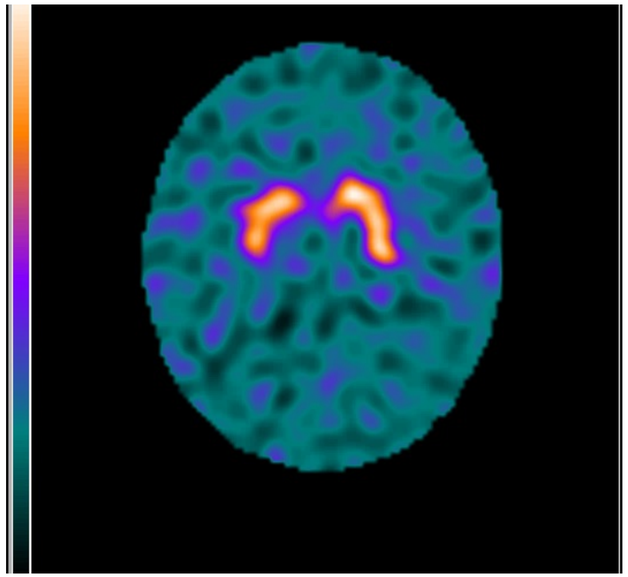
Images courtesy of GE Healthcare and Spectrum Dynamics

Software Evolution

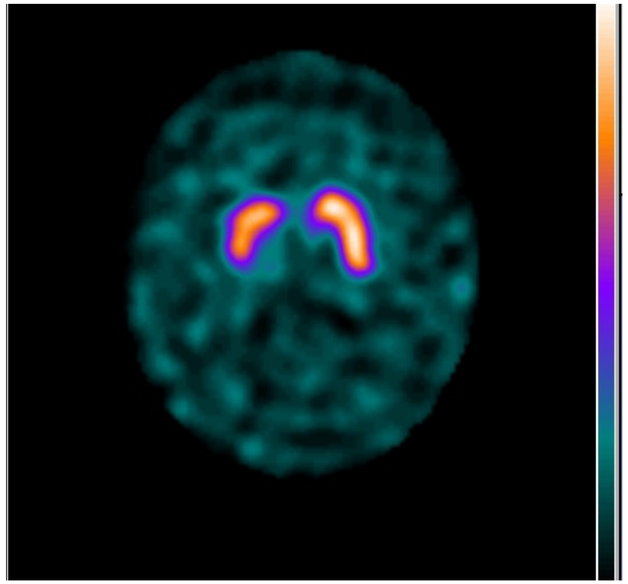

Resolution
Modelling
Scatter
Correction
Attenuation
Correction
Iterative
Reonstruction

Iterative Reconstruction

- Traditionally SPECT was reconstructed using filtered back projection (FBP)
  - Streak artefacts
  - Difficult to incorporate corrections for physical effects
- Iterative reconstruction has become increasingly popular since the introduction of SPECT/CT
  - Default



Filtered Back Projection



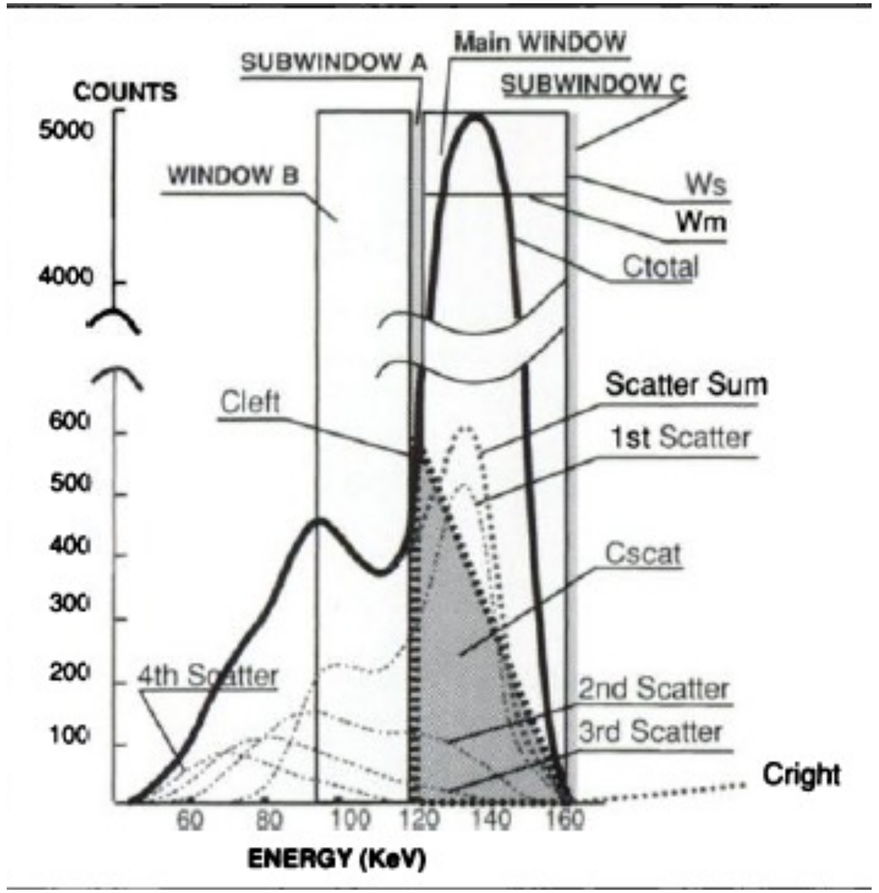
Iterative Reconstruction

Corrections: Attenuation

- Attenuation can be problematic in larger patients
  - Myocardial perfusion
- CT is a map of attenuation
- Bi-linear correction of attenuation at CT and SPECT photon energies
  - e.g. one linear relationship < 0 HU and another > 0 HU
  - Changes with radionuclide
- Apply in iterative reconstruction

Scatter Correction

- Scatter correction mostly done through multiple energy window estimation of scatter contribution
- Advanced Monte Carlo based solutions now available.



Ichihara et al J. Nucl Med (1993), 2216-2221

Spatial Resolution

The largest degradation of quantification

- SPECT resolution is typically 8-10 mm
- Can account for resolution losses in iterative reconstruction
  - Improves resolution
  - Improves noise characteristics
  - Can lead to artefact
- Extra resolution improvements can be made by deconvolution or other methods
  - Partial Volume Correction

PET/CT vs SPECT/CT

Can SPECT/CT be fully quantitative?

Corrections	PET/CT	SPECT/CT
Attenuation	Yes	
Scatter	Yes	
Resolution	Yes	
Sensitivity Calibration	Yes	

PET/CT vs SPECT/CT

Can SPECT/CT be fully quantitative?

Corrections	PET/CT	SPECT/CT
Attenuation	Yes	Yes
Scatter	Yes	Yes
Resolution	Yes	Yes
Sensitivity Calibration	Yes	Yes

SPECT/CT **can** be a fully quantitative (kBq/ml) modality

Applications

Molecular Radiotherapy (MRT)

Thyroid I131	Neuroendocrine Tumours I131 MIBG	Neuroendocrine Tumours Lu-177 Peptides	Hepatic mets. Y-90 Microspheres	Prostate Ca Lu-177 PSMA

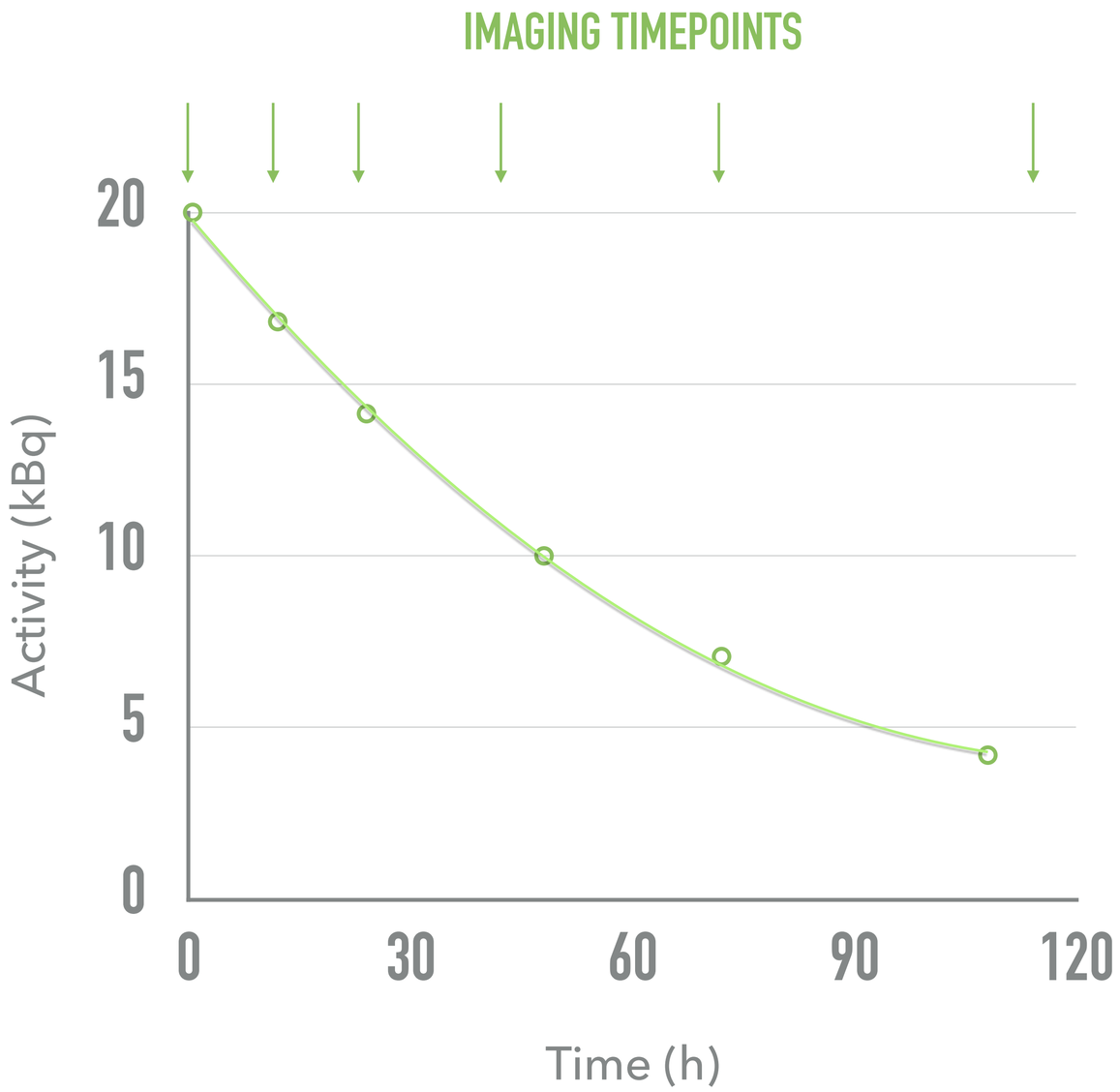
- MRT = Beta or Alpha labelled radiopharmaceutical giving targeted therapy
  - Many also emit gamma photons which can be imaged
- Can use multiple time point imaging to determine time vs activity curves
  ⇒ organ/tumour dose

MRT Dosimetry

MIRD

$$\bar{D} = \tilde{A} \times S$$

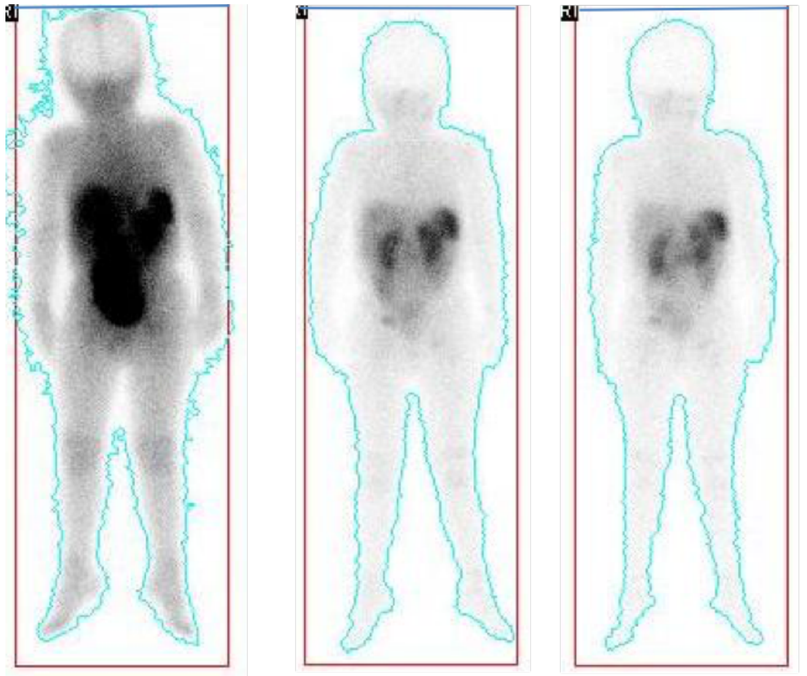
- $\bar{D}$: Mean absorbed dose (organ, tissue or tumour)
- $\tilde{A}$: Cumulated Activity
- S: MIRD S-factor gives radionuclide specific absorbed dose per unit activity



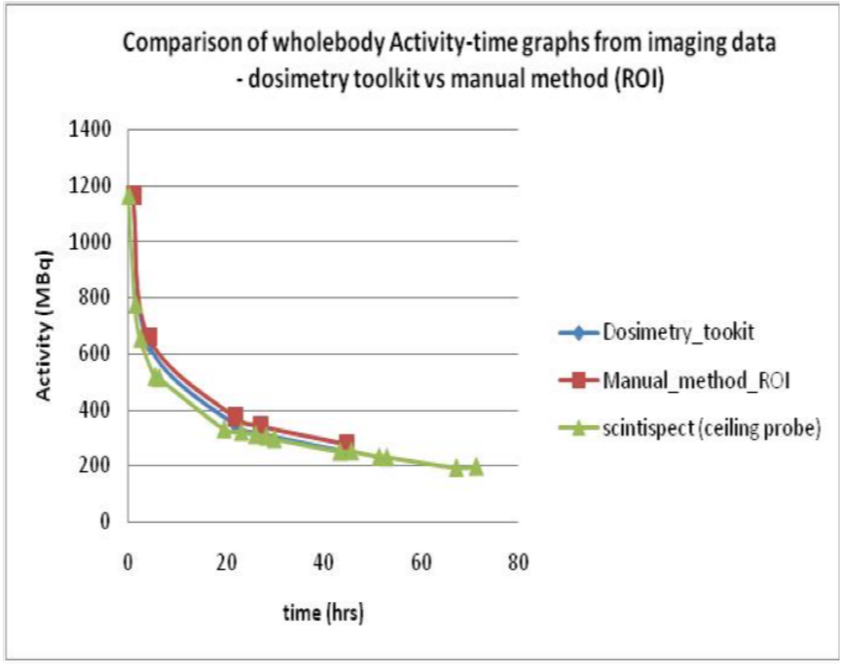
Dosimetry

Historically

- Multiple time point 2D imaging
  - Geometric mean to of region of interest counts to account for attenuation
- Occasional SPECT
  - To improve accuracy of quantification
- Use of an imaging standard to convert counts to activity
- Determine accumulated activity and then dose



T= 1.05 hrs T= 21.85 hrs T= 44.80 hrs



Dosimetry using Quantitative SPECT

- Multiple time point imaging
- Quantitative SPECT (kBq/ml)
- 3D Segmentation of tumours and organs at risk
- Registration of multiple time point data
- Real Time vs activity curves based on 3D Data
  - Inbuilt sensitivity calibration to directly give kBq vs time
- Organ and tumour doses

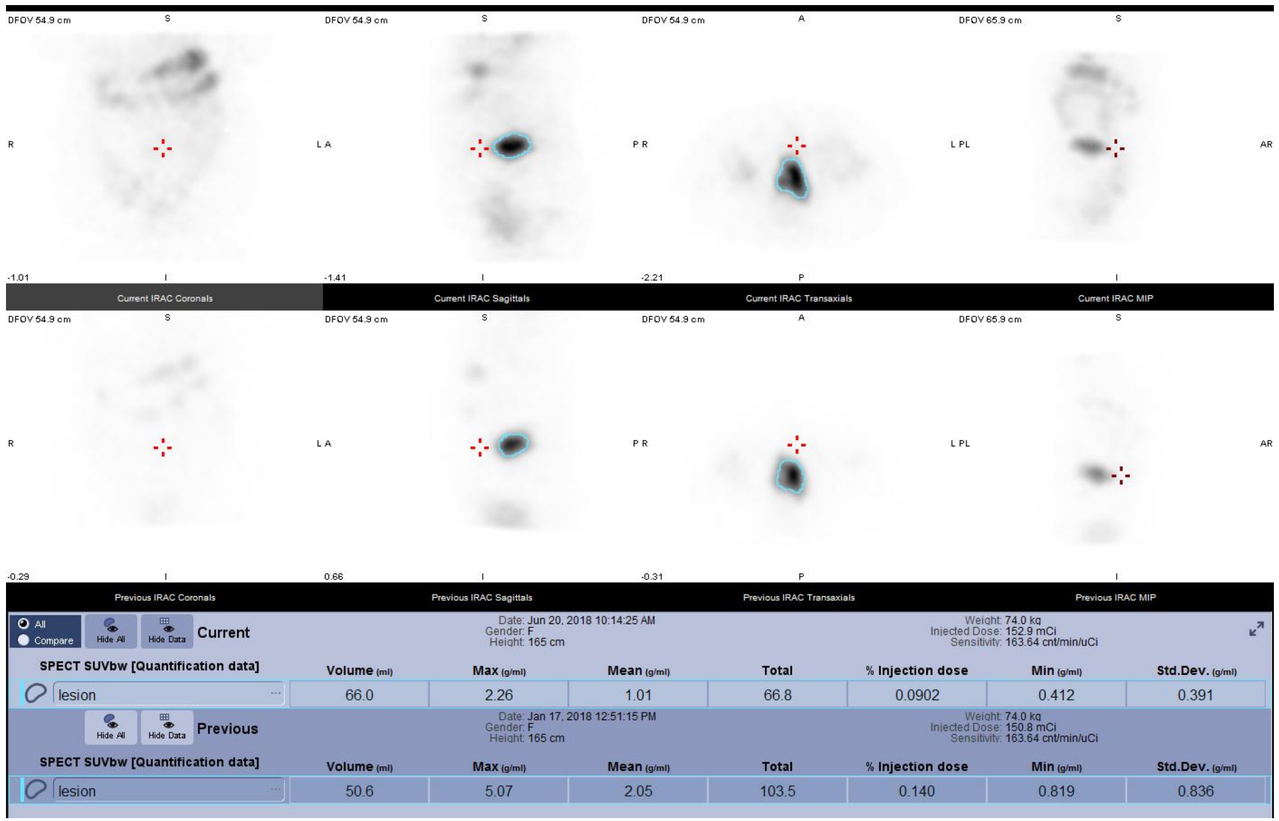
There are multiple commercial softwares that can help you to do this

Dosimetry is a key application of quantitative SPECT …..

But there is more!

Theranostics

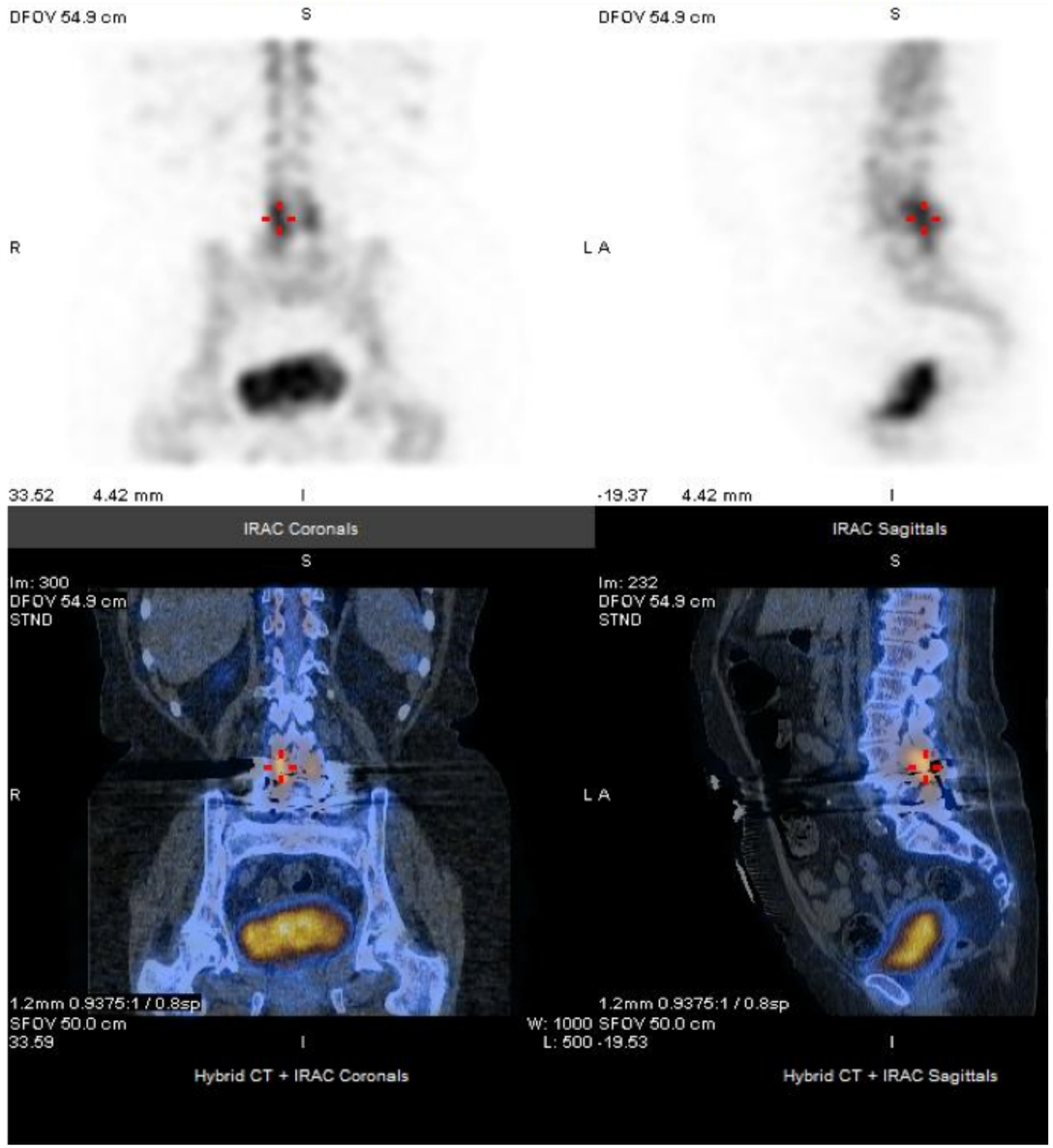
- Labelling a therapeutic with a pure gamma emitting radionuclide we can:
  - Stage
  - Assess disease progression
  - Look at treatment response
- Qualitative SPECT
  - Visually assess changes
- Quantitative SPECT
  - Look at quantitative change in tumour uptake
  - Look at total tumour burden
    Sum of volumes x activities



Bone

Orthopaedic and Cancer

- Prosthetic loosening
  - Longitudinal imaging
- Degeneration
- Total (bone) metastatic burden
  - Sum of uptake-volume products within a body scan



Cardiology

Amyloidosis and Perfusion

- Cardiac Amyloidosis
  - 2D DPD imaging
  - Qualitative scale
  - Option for 3D quantitative imaging to characterise level of amyloidosis
- Perfusion
  - Typically assess relative perfusion within heart
  - Absolute uptake could provide benefits

Challenges

Challenges

New technology brings new challenges

- SPECT field of view is 40cm
  - Small field of view imaging can be quick
  - Larger field of view imaging e.g. total body is much slower
  - But ring geometry CZT SPECT scanners will significantly reduce this time
- Need to consider time of imaging
  - Radiopharmaceutical uptake depends on timing
- Need to consider interacting drugs
  - Not important for visual assessment
- And there is the sensitivity calibration to perform too and recording of administration time and activity

Summary

- Quantitative SPECT is available now!
  - Due to hardware and software improvements
- It requires a little more work
  - Tasks
  - Scan time
- Really valuable applications
  - Dosimetry and theranostics
  - Other applications too


That you for watching !