Επεξεργασία και Ανάλυση Δεδομένων στη Πυρηνική Ιατρική

Εφαρμογές στη SPECT Απεικόνιση

Single Photon Emission Computed Tomography (SPECT)

Image Reconstruction and Processing

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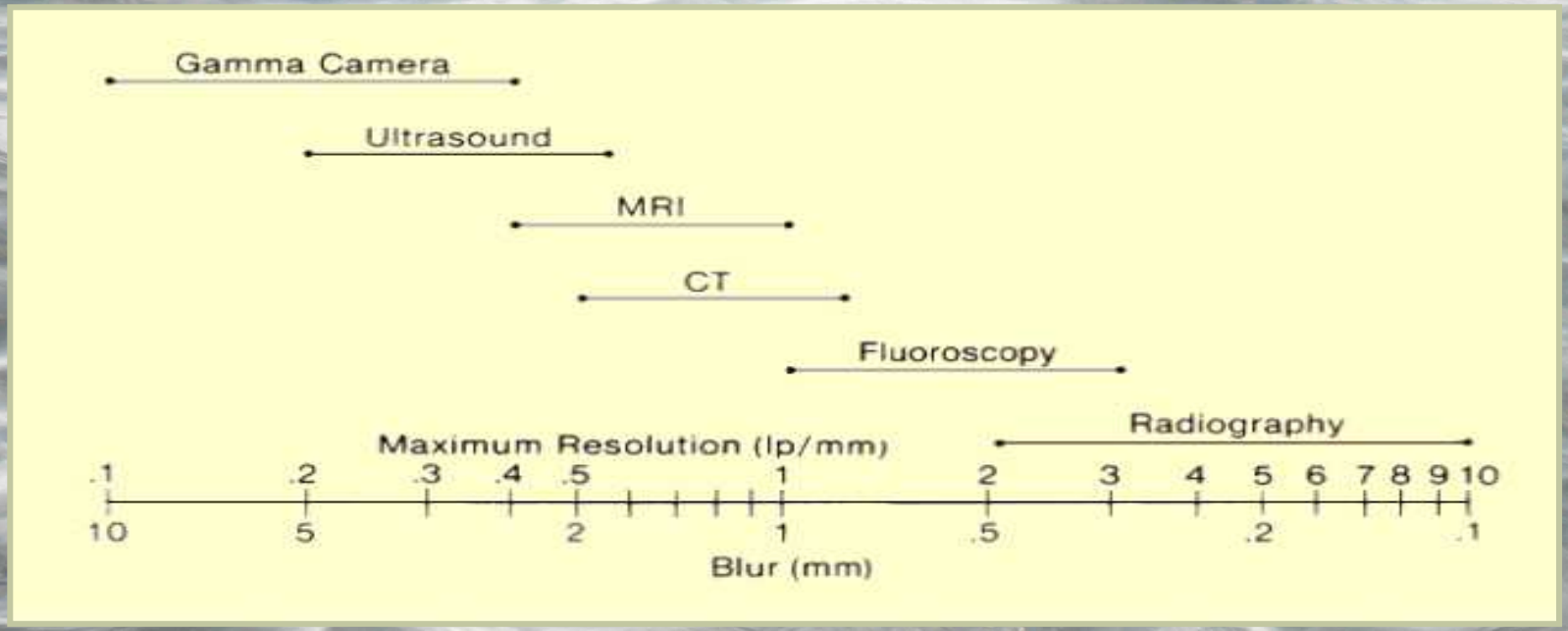
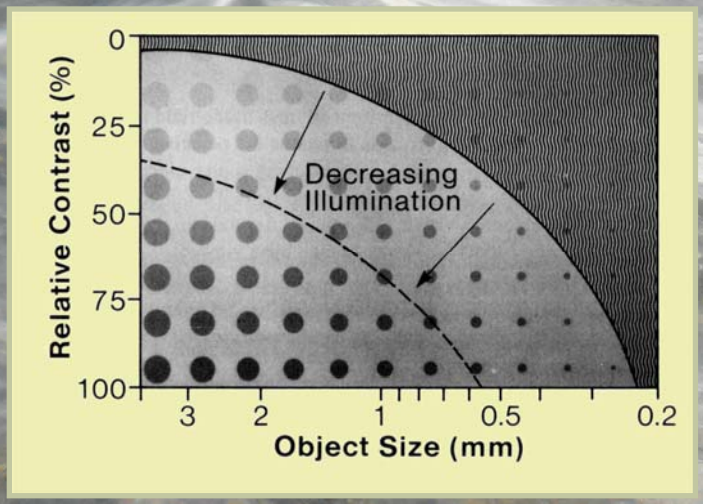
Comparison of Medical Images quality parameters





Nuclear medicine images often suffer from low contrast that is further degraded by the noise introduced in the process of imaging

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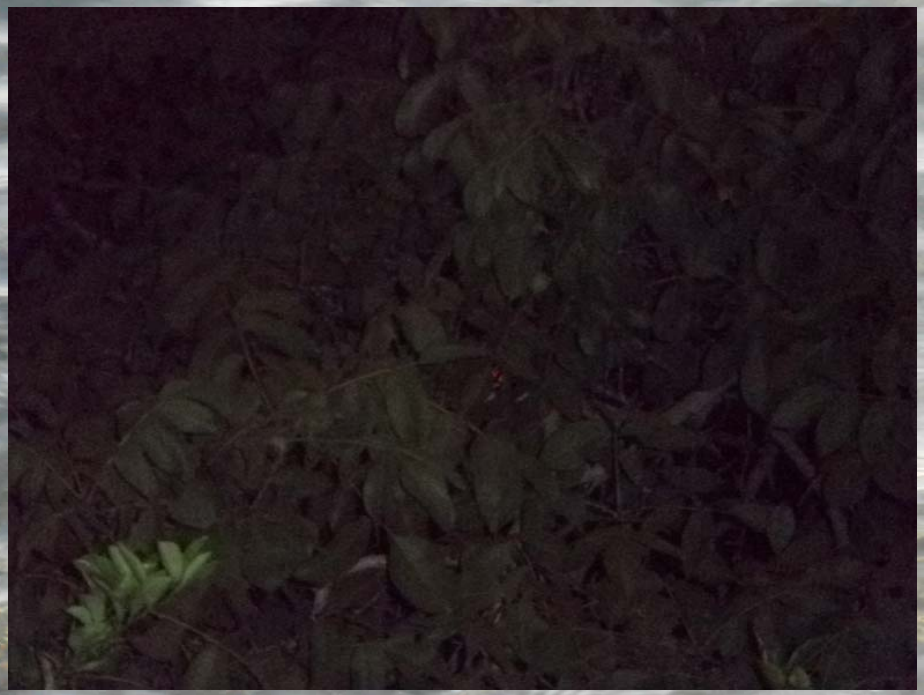
- By image processing we try correct image parameters as exposure or contrast or low count statistics



- By image processing we can correct artefacts

- By SPECT reconstruction & processing

We try to emerge information from depth

• Digital Image concept

sampling

continuous-sample image

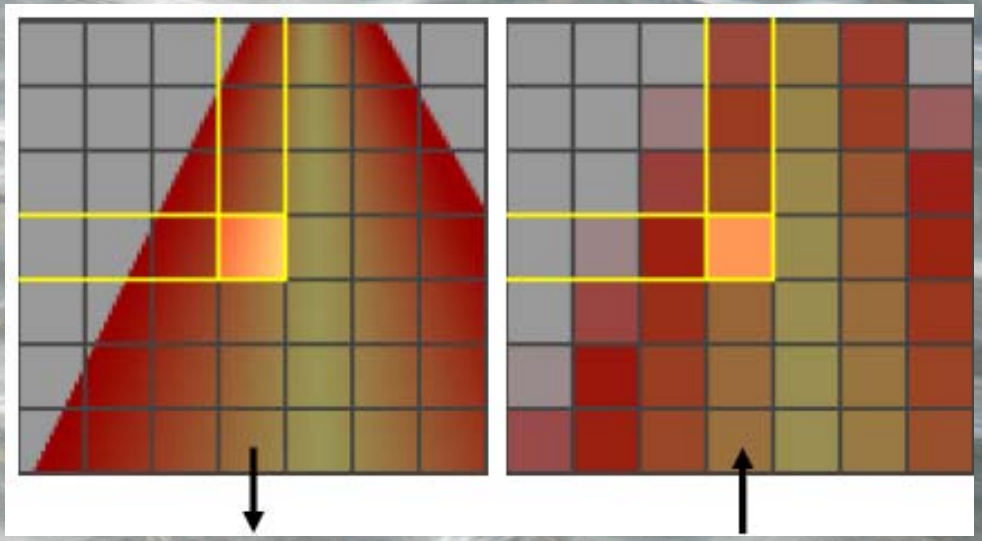
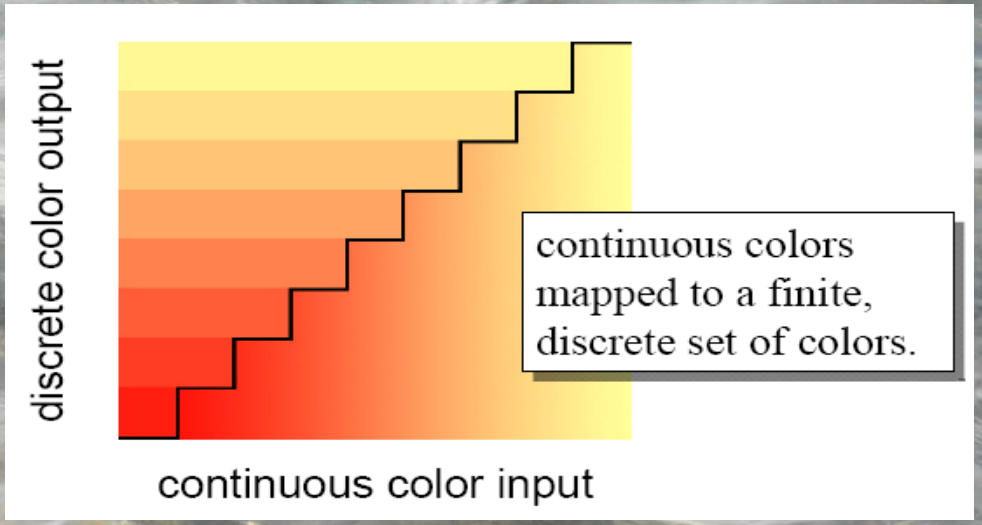


Image formation-quantization



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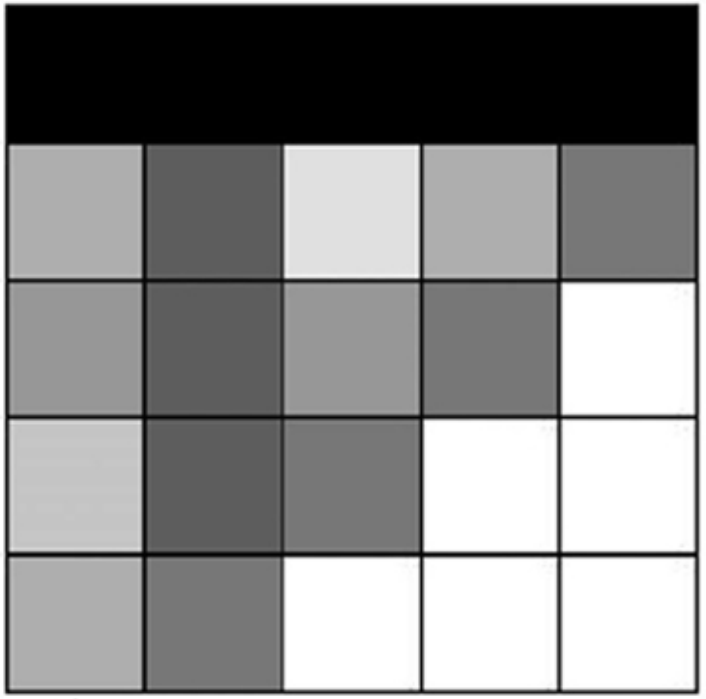
Digital Image formation

α)image 5χ5 pixels/grey levels 0(black)- 7(white)
b) Numerical representation



a)

0	0	0	0	0
4	1	6	4	2
3	1	3	2	7
5	1	2	7	7
4	2	7	7	7

b)

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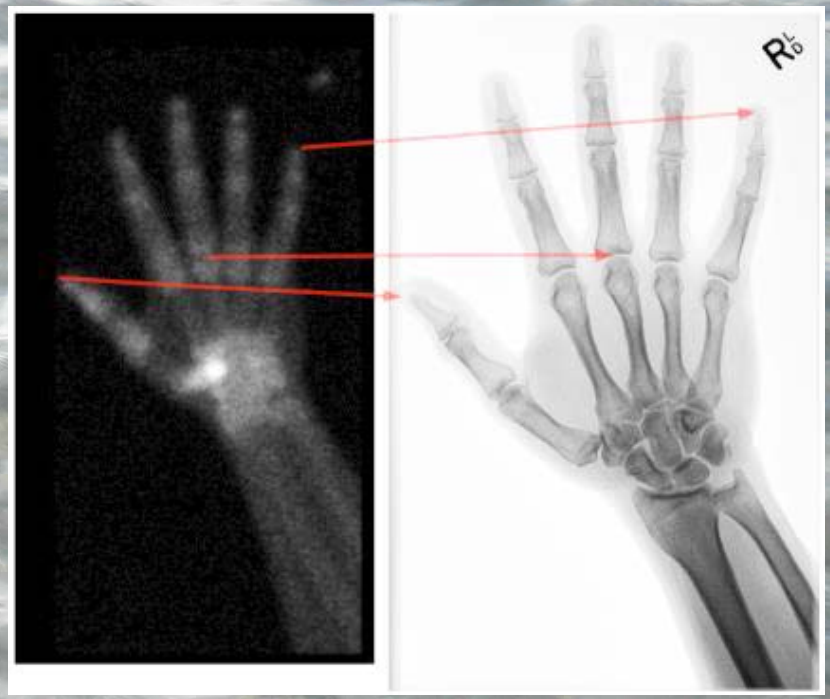
Digital Image formation
Pixels

- **A digital image, *I*, is a mapping from a 2D grid of uniformly spaced discrete points.**

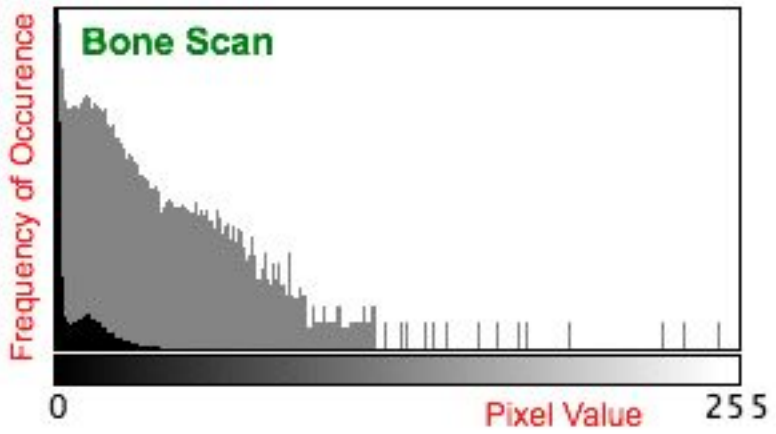
- **At each column location in each row of *I* there is a value.**
- **The pair (*p*, *I*(*p*)) is called a "pixel" (for *picture element*).**

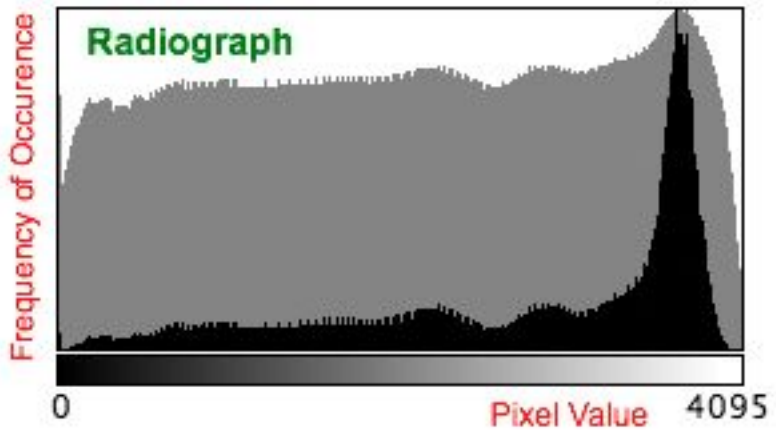
- ***p* = (*r*,*c*) is the pixel location indexed by row, *r*, and column, *c*.**
- ***I*(*p*) = *I*(*r*,*c*) is the value of the pixel at location *p*.**

Comparison of Nuclear medicine images with radiographs



It is important to use the overall distribution of grey levels for obtaining meaningful regions.





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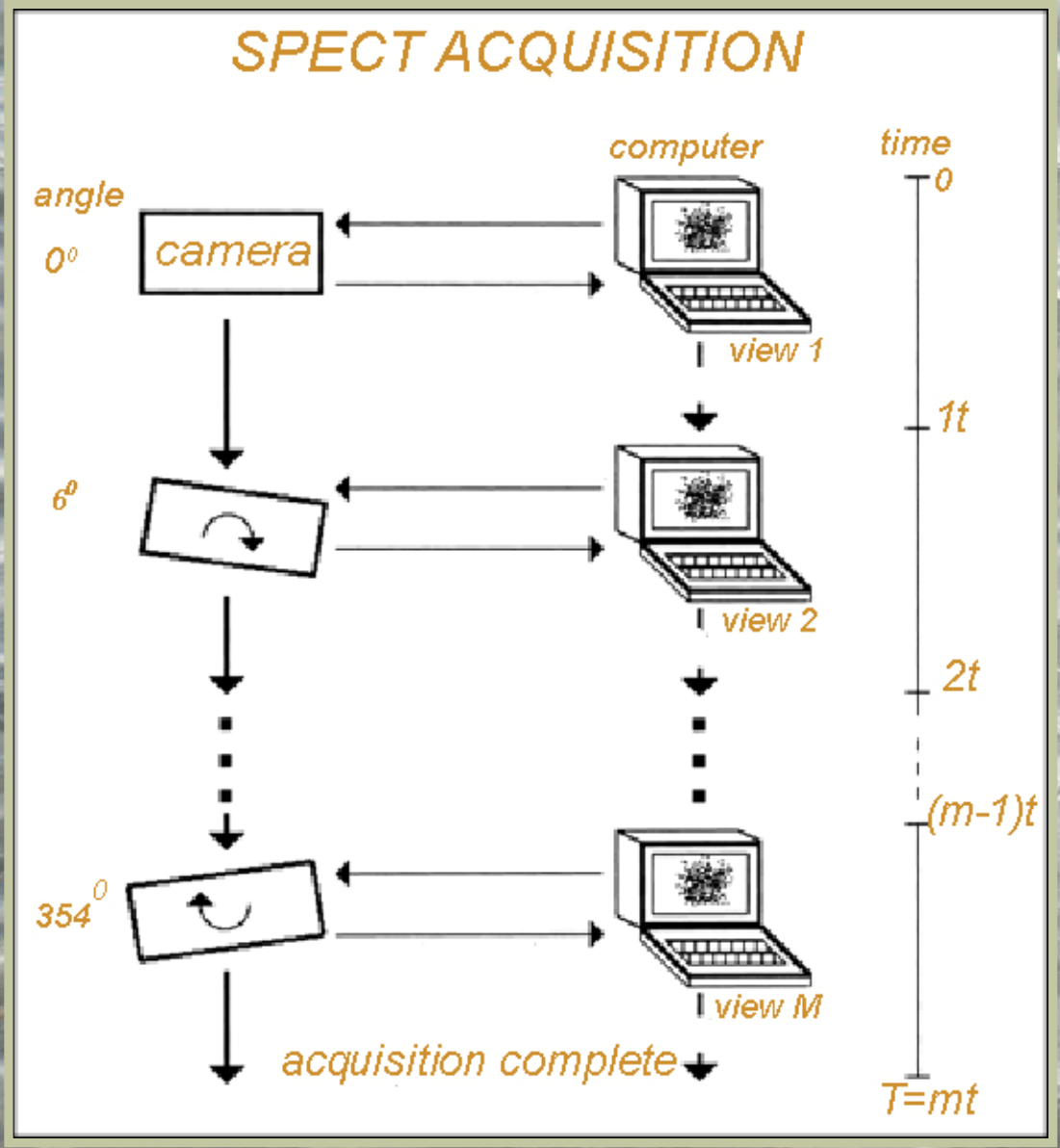

Acquisition Pixel Size selection

The pixel size is selected in a combination of **field of view, matrix size and zoom factor.**

typically 3.5 - 4.0mm seems optimal

Count Density

If insufficient counts are acquired:

Low counts in normals will result in use of more smoothing filter which will create a lower resolution image potentially result

↓

in an **abnormal image**.

Normals will be easy with high quality images.

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IMAGE DEGRADING FACTORS

- Statistical Noise
  - *Noise in projection data and reconstructed images*
- Attenuation
  - *lower intensity, artifactual non-uniform intensity*
- Scatter
  - *Lower image contrast, artifactual non-uniform intensity*
- Collimator-detector
  - *blurring, artifactual non-uniform resolution*
- Patient motions
  - *blurring, artifactual non-uniform intensity*

Image blurring by motion Correction?

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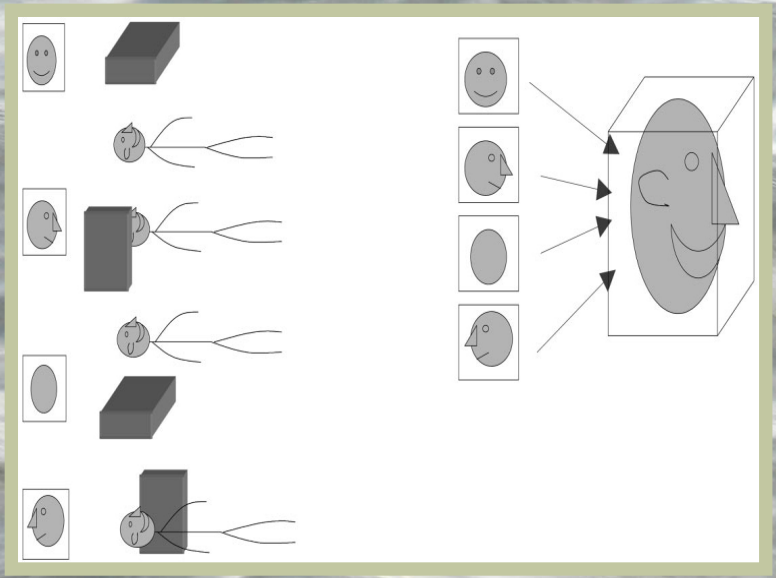
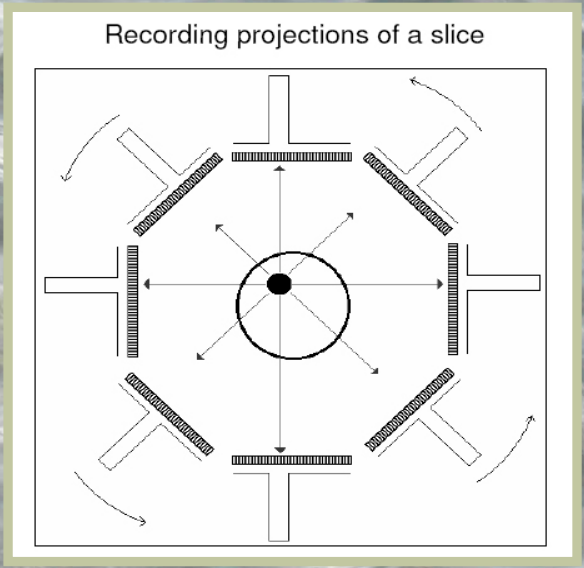
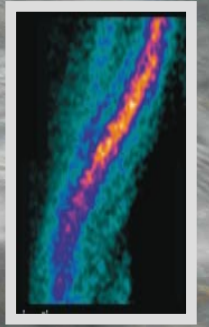
SPECT acquisition/ patient – organ motion correction





- **Inspection of cine display of planar projections (ie, rotating images) is the recommended method of detecting motion as it demonstrates both vertical and horizontal motion.**

- ***A static sinogram is also sometimes used, but does not show horizontal motion.***



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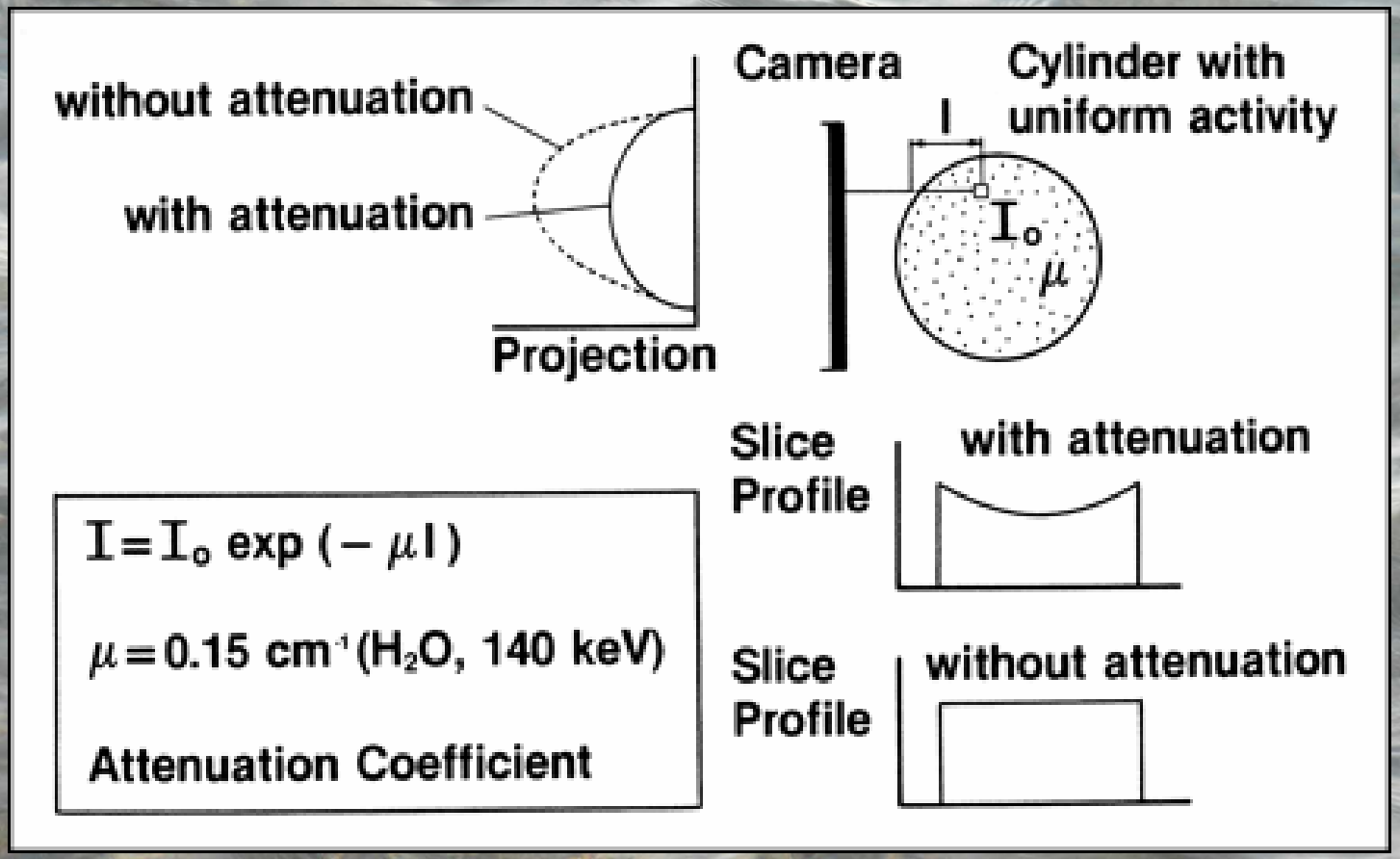
Attenuation Correction



Attenuation Correction

Cine display of angular projection images for identifying the sources of attenuation.

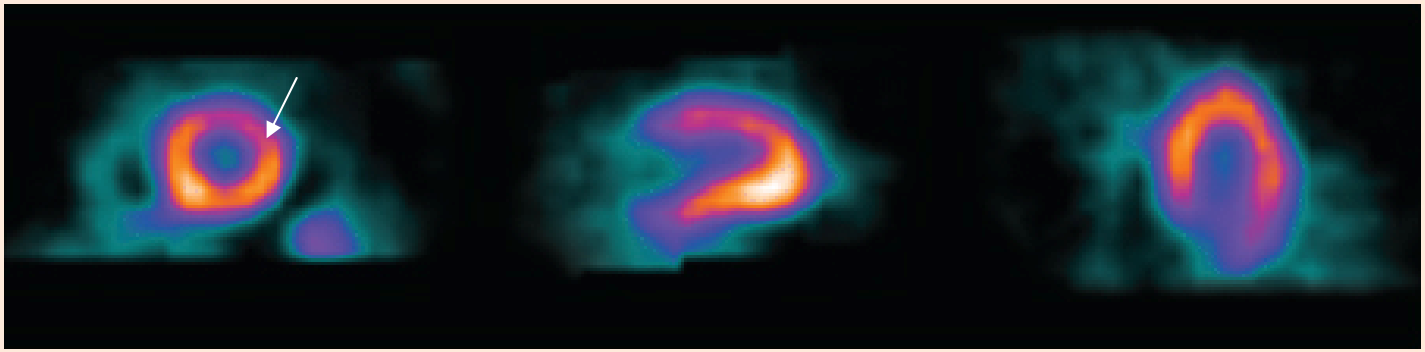
- ***If automated attenuation correction is used,***
  The data should be processed

  1. **first without attenuation correction and then**
  2. **reprocessed with attenuation correction.**

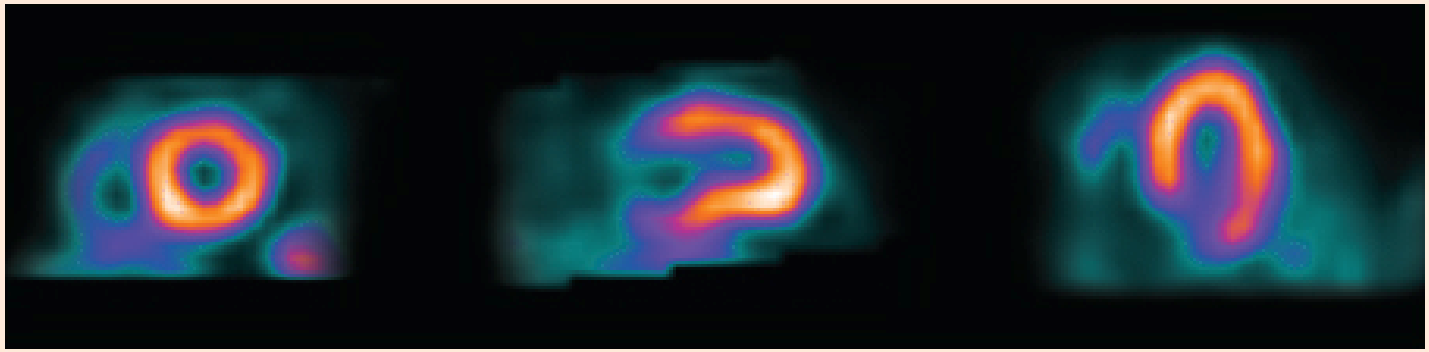
- **The corrected and uncorrected data should be read simultaneously, as the former may contain artefacts or overcorrections.**

Breast attenuation deteriorates resolution

No attenuation correction

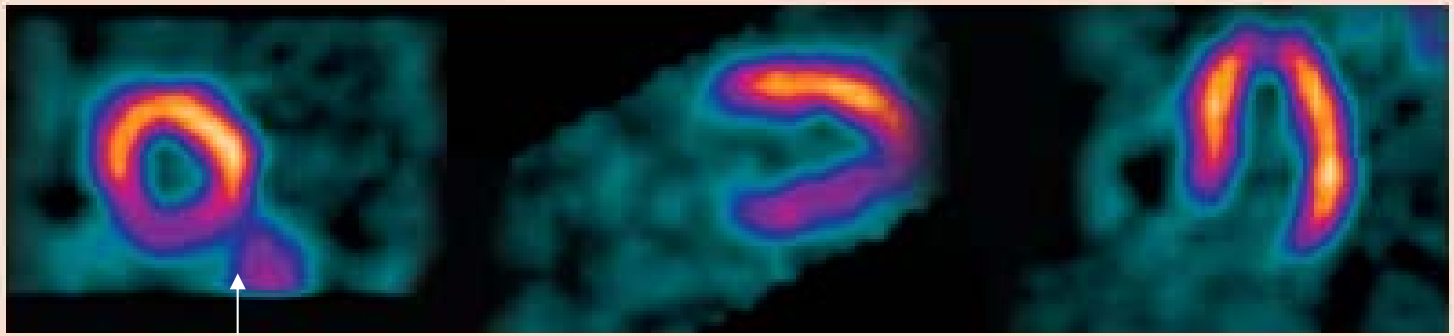


Attenuation correction

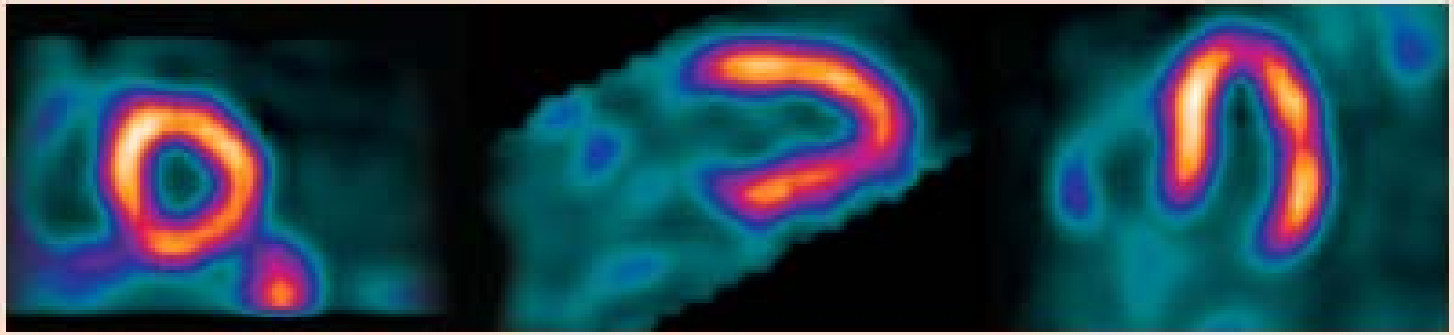


Subdiaphragmatic uptake

No attenuation correction



Attenuation correction



Attenuation Correction

By

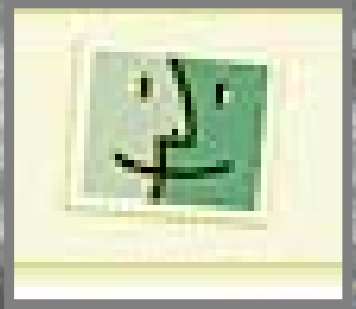
- Transmission image

By

- External source (rotating, point, line) or
- Attenuation correction by a CT scan

Registration

the transmission and emission images must be accurately aligned



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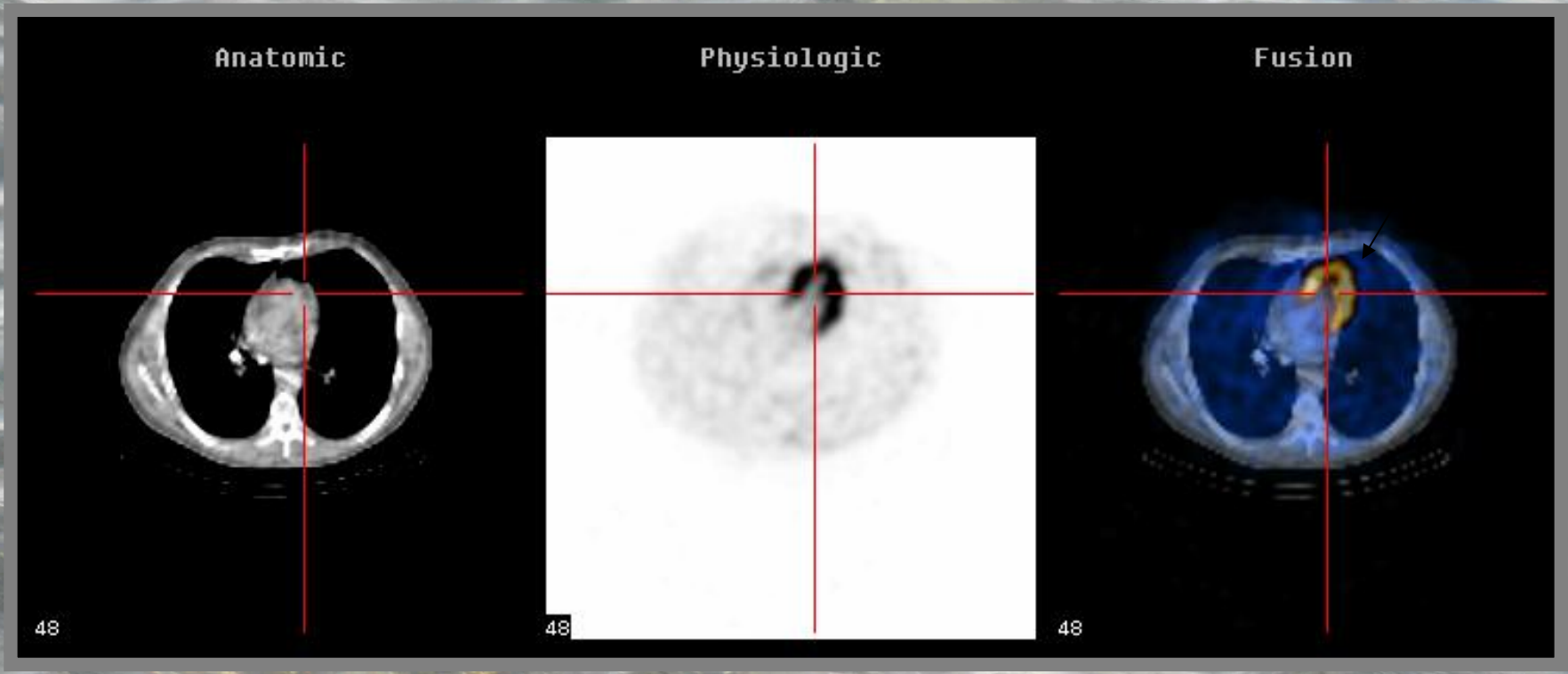
Mal-registration of AC scan



Images showing mal-registration of the emission data and the transmission AC map

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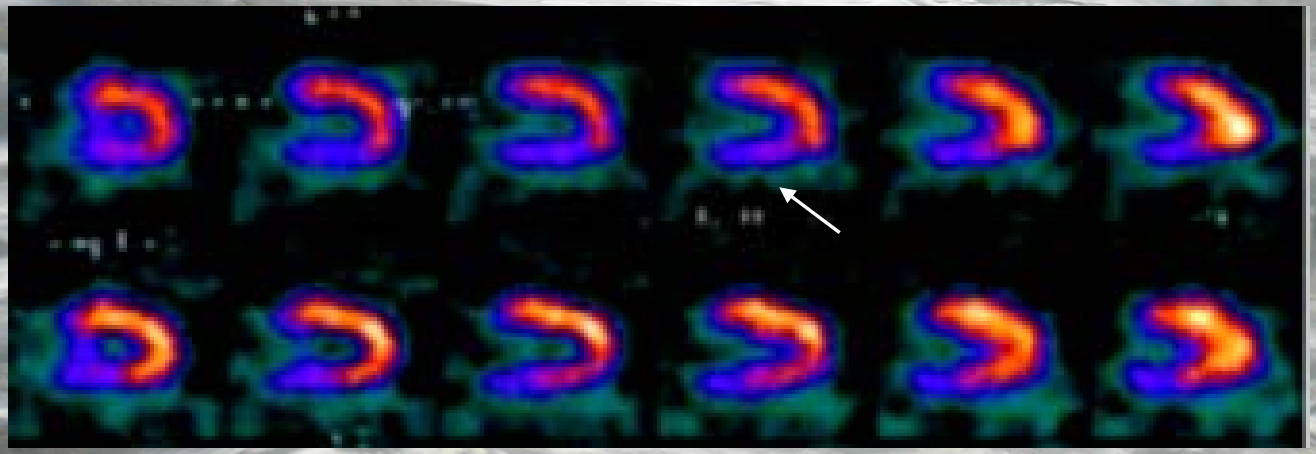
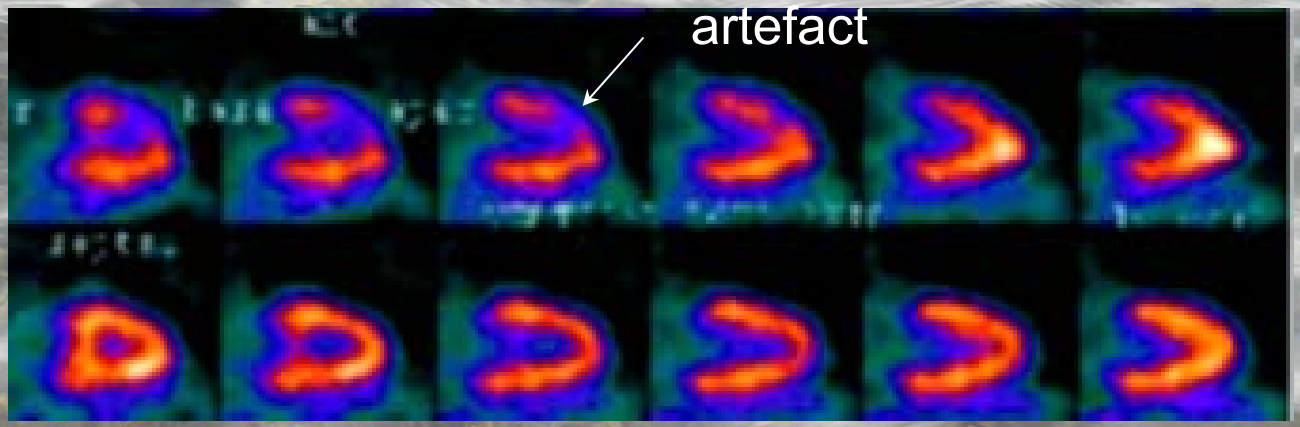
Impact of mal-registered AC map on the reconstructed images



SPECT reconstruction without AC application



Reconstruction including attenuation correction using mal-registered AC scan

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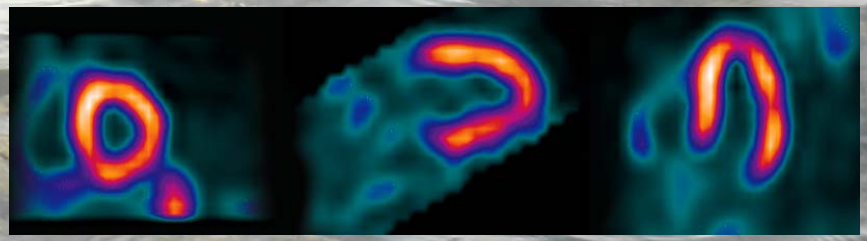
Reconstruction—

A wide variety of reconstruction filters are used, based on

1. tracer characteristics and activity,
2. system and collimator characteristics,
3. software used for analysis.

In myocardium reconstruction SPECT data are reoriented to the 3 axes of the patient's heart

horizontal long axis, vertical long axis, and short axis slices.



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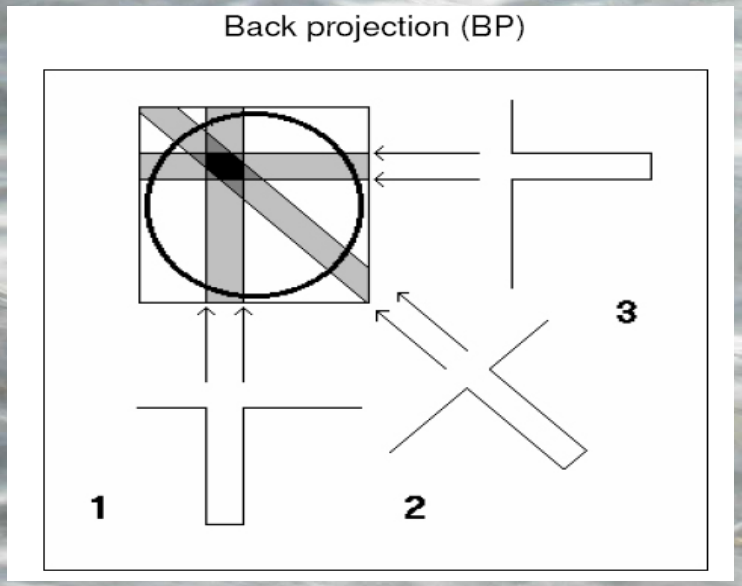
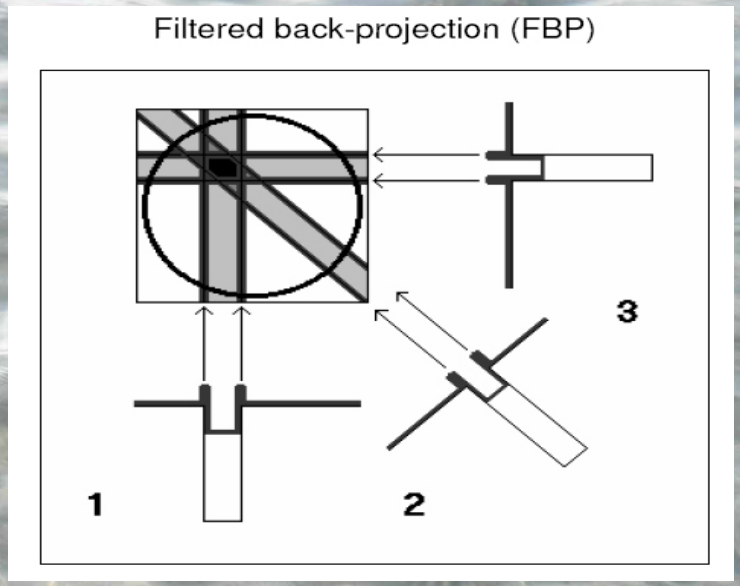
Reconstruction-Processing

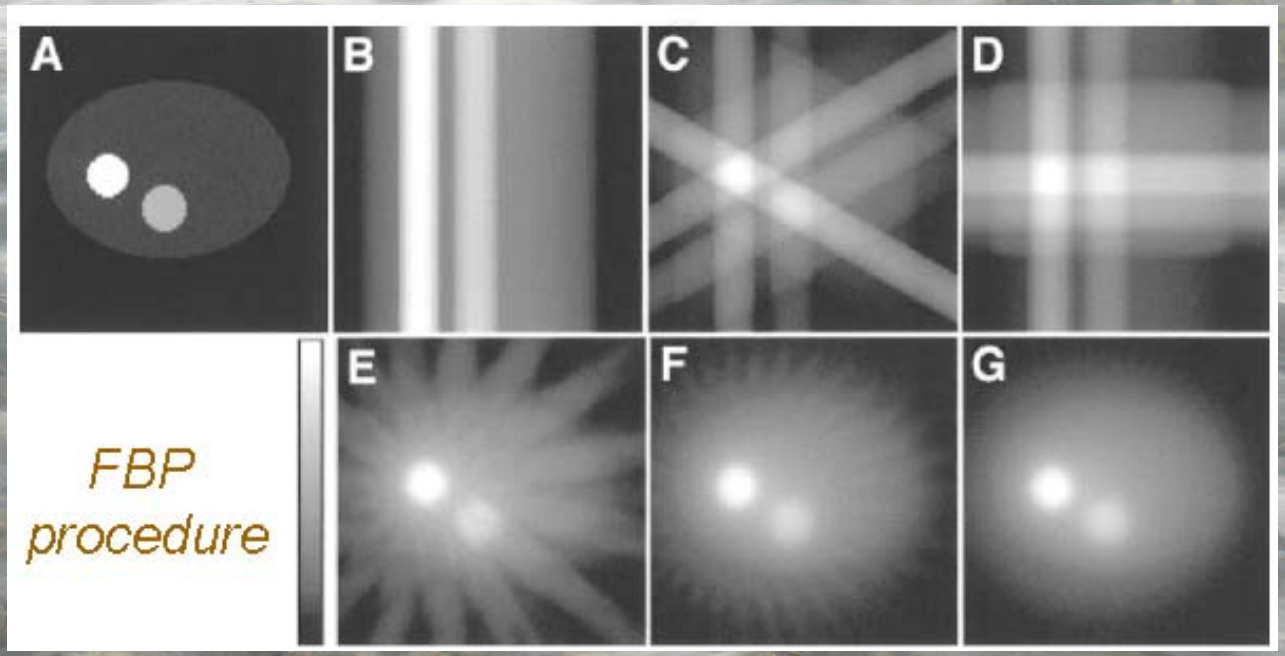
- Classical
  filtered backprojection (FBP) and

- Iterative statistical image reconstruction algorithms

1. Maximum Likelihood Expectation Maximization (MLEM)
2. Ordered Subsets Expectation Maximization (OSEM)







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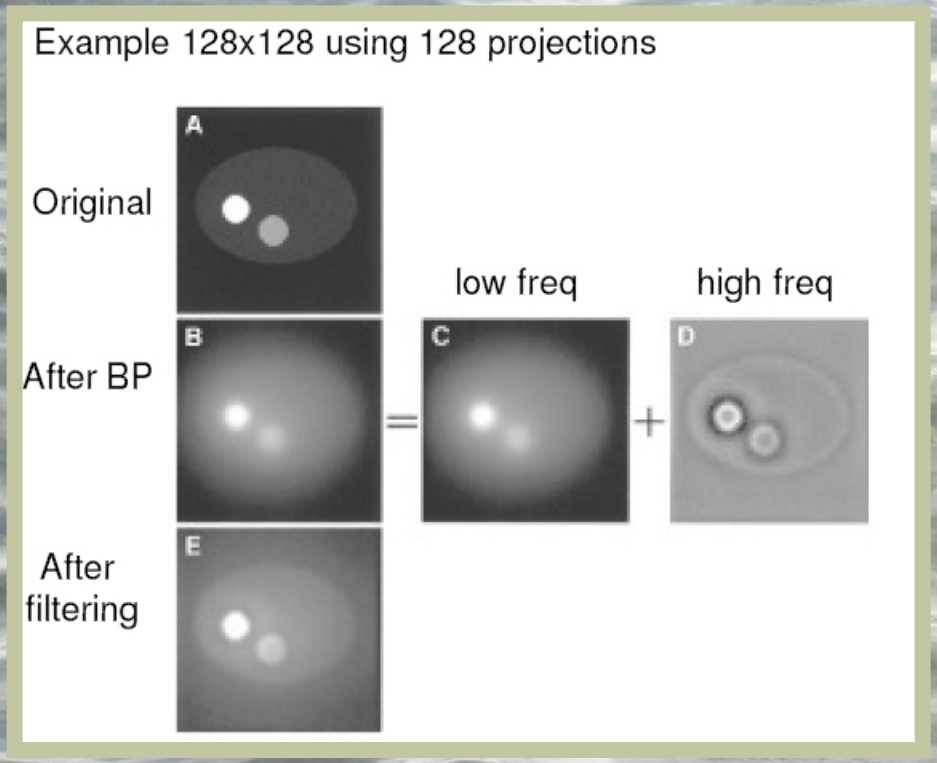
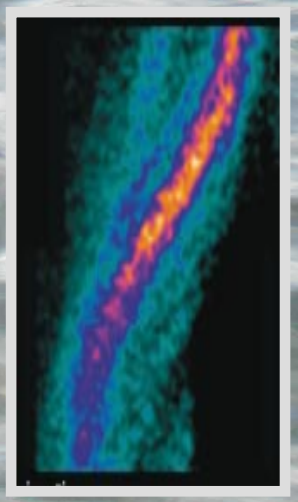
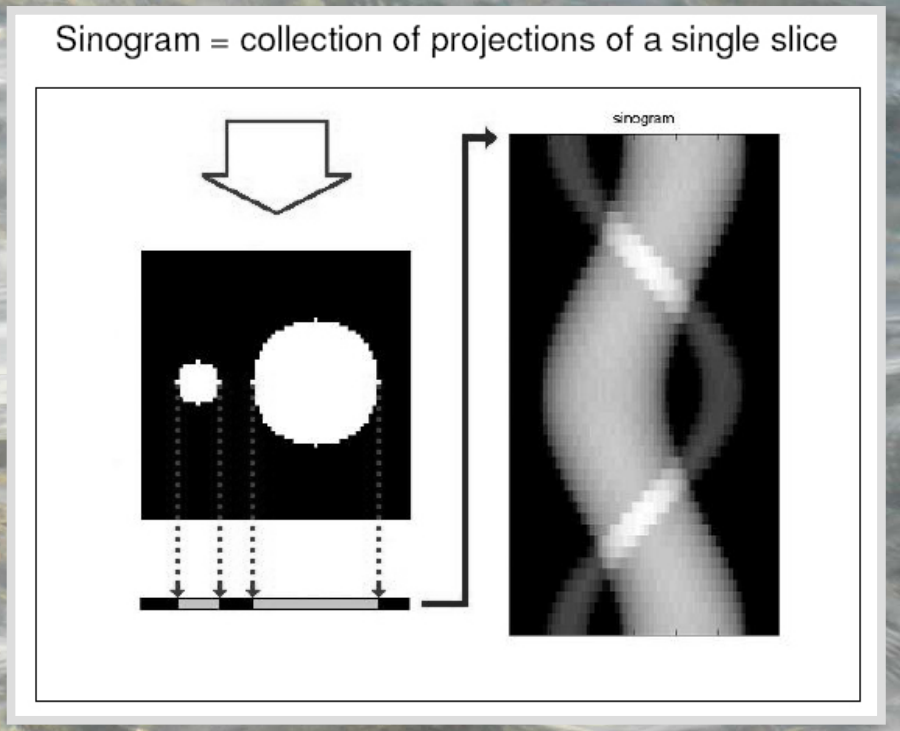


SINOGRAM





FBP

- **Very fast**
- Direct inversion of the projection formula
- **Difficulties for Corrections of scatter, non-uniform attenuation.**
- **Needs a lot of filtering**

blurring vs noise

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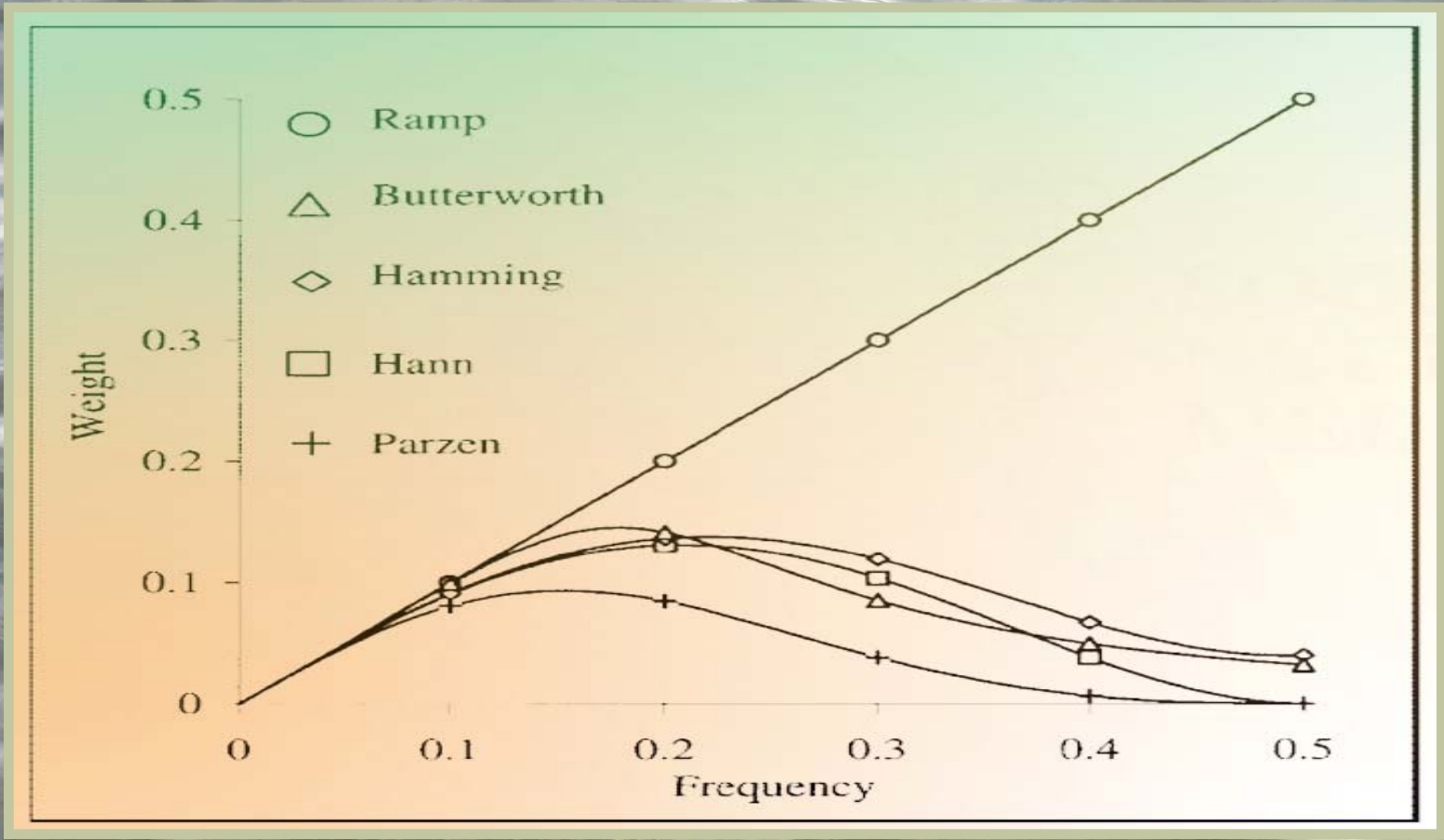
—Filtering

helps improve image clarity

by removing noise and blur before and after backprojection of raw SPECT data.



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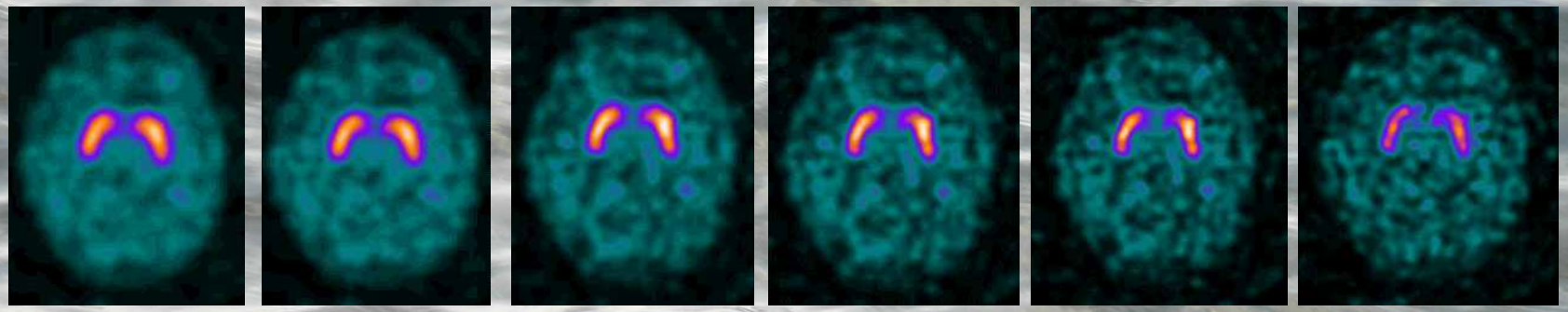
Reconstruction Filter Choice /DaTScan Normal Study



0.4 0.45 0.55 0.65 0.75 0.85

SPECT Post Butterworth Filter - Order 6, Variable Cut-off (cycles/cm)

185MBq, Single Head, High Resln Parallel Collimator, 40 secs per projection, 64 projections, 3.2mm pixel size.

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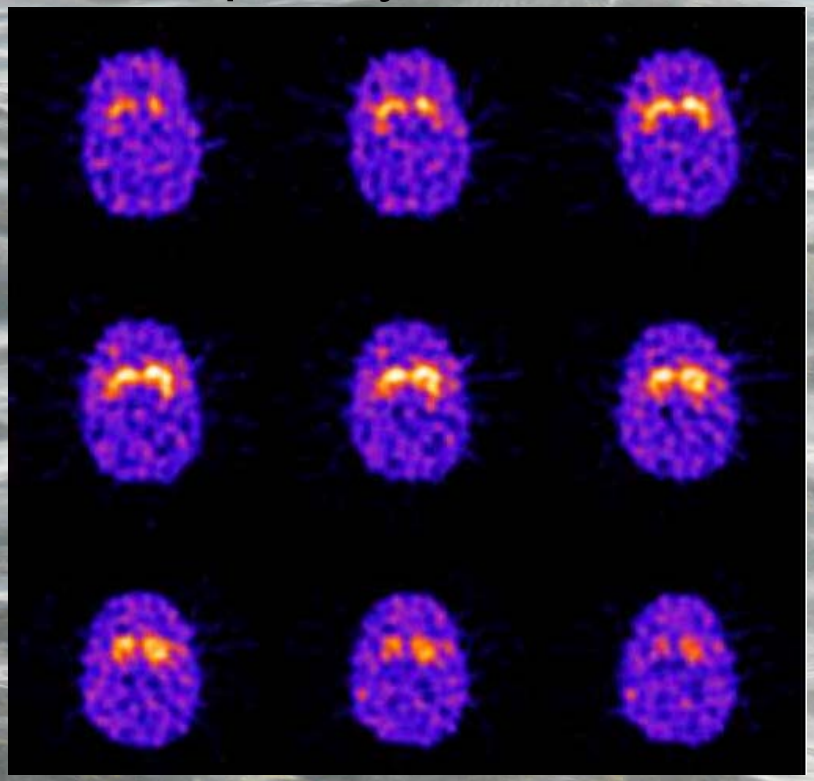
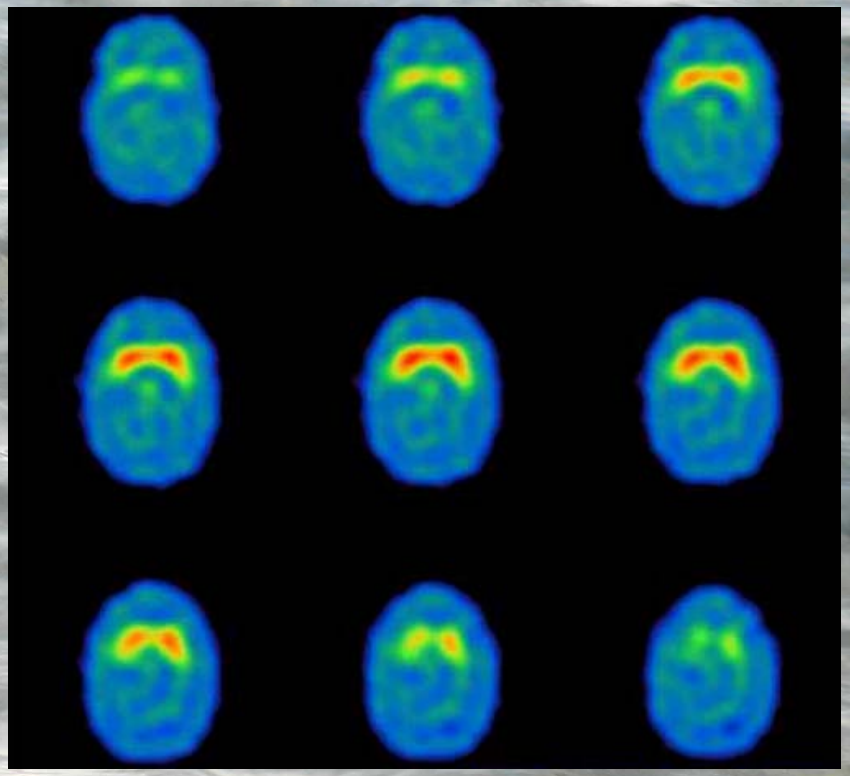
Effect of filter choice

Adequately filtered



oversmoothed



- Many times data looks ‘noisy’ due to the fact that the background activity is low in normals. ***This does not affect diagnostic accuracy.***
- Encourage the use of less smoothing filters if acquisition parameters are correct.

•Many centres use a filter smoothing the data too heavily.

Do not change filter in ‘abnormal’ studies.

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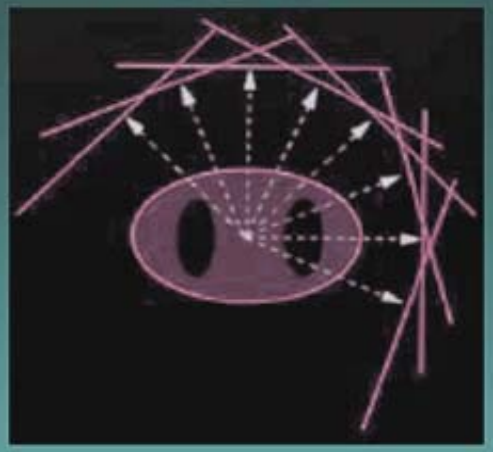
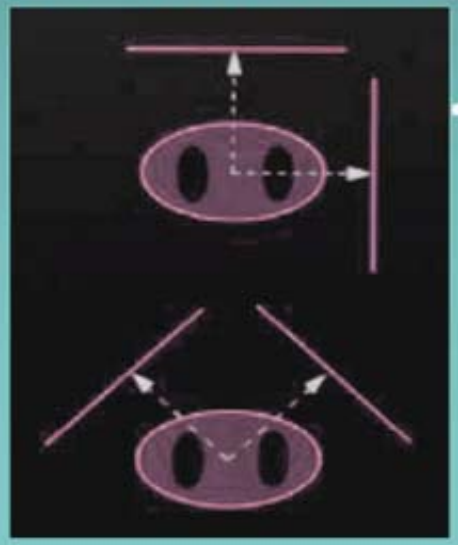
Conventional ML-EM algorithm



- In each iteration
  - compute errors from all views
  - update image

OS-EM or Block Iterative algorithm



- In each iteration
  - compute errors from 2 or more views
  - update image
  - compute errors from another subset of views
  - update image
  - and so on ….

ITERATIVE RECONSTRUCTION

Long calculation time
Amplification of noise

but

Easy to handle projection noise when counts are low

Model the imaging physics – geometry-nonuniform attenuation- scatter- depth dependent resolution

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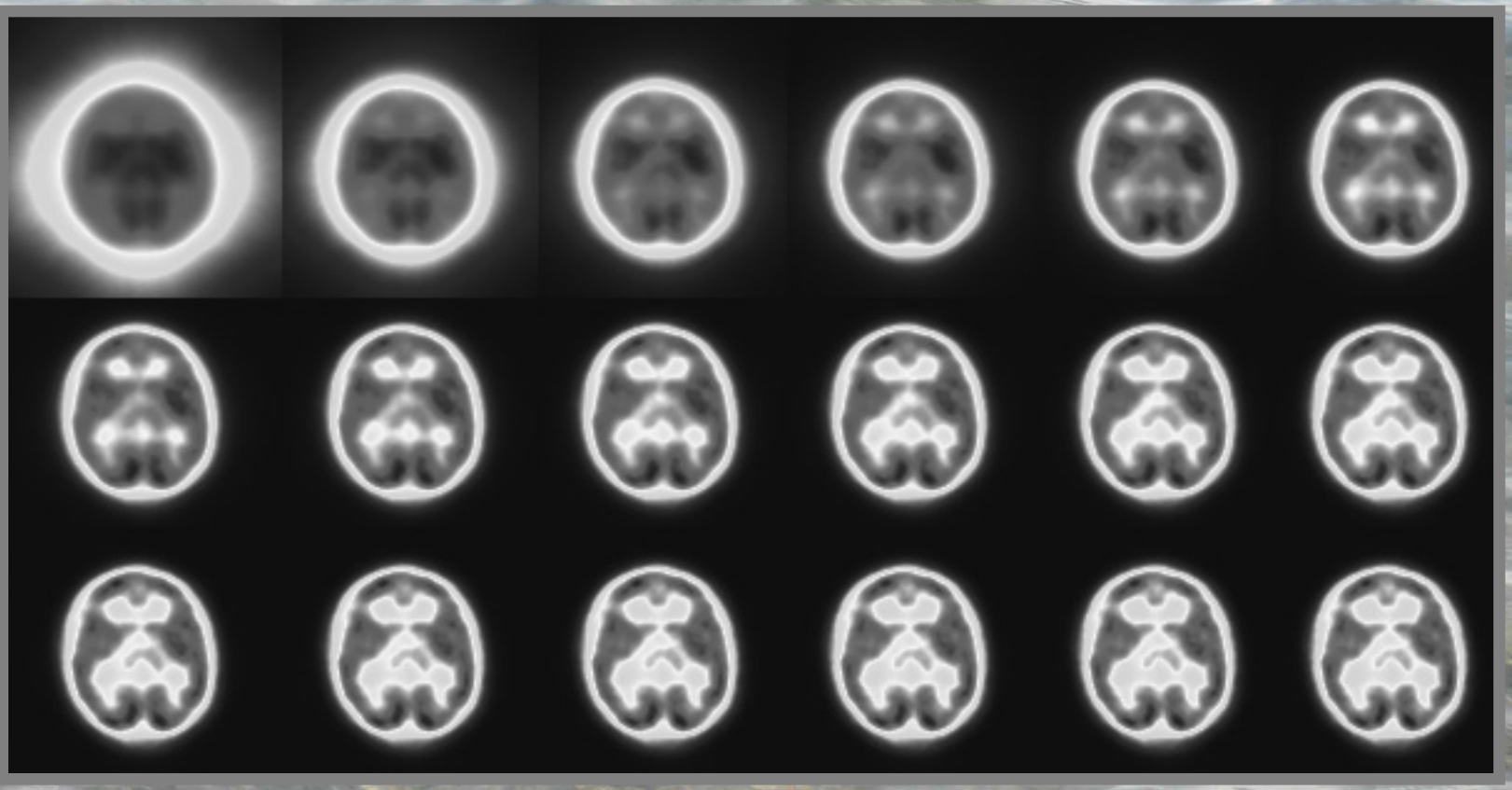
ML-EM maximum likelihood expectation maximization
Sequence of iterations



Differences of subsequent iterations -------estimated image

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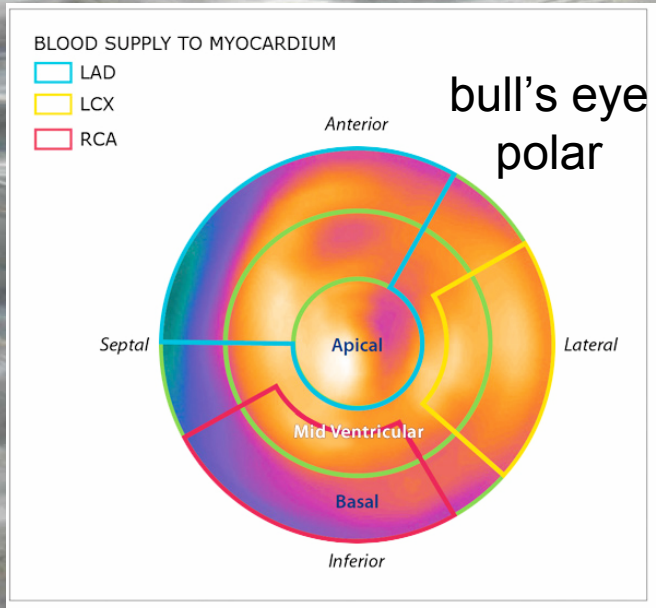
Quantification—

- **A number of software packages *(provided by vendors)* are available for quantification of myocardial, brain, kidneys and other organs' slices.**
- **Mathematical algorithms *(e.g. by Matlab or IDL languages)* are also used for 3D rendering images evaluation**



***17 segments* of the coronary arterial territories corresponding to**
1. the left anterior descending artery *(LAD),*
2. right coronary artery *(RCA),*
3. left circumflex coronary artery *(LC X)*

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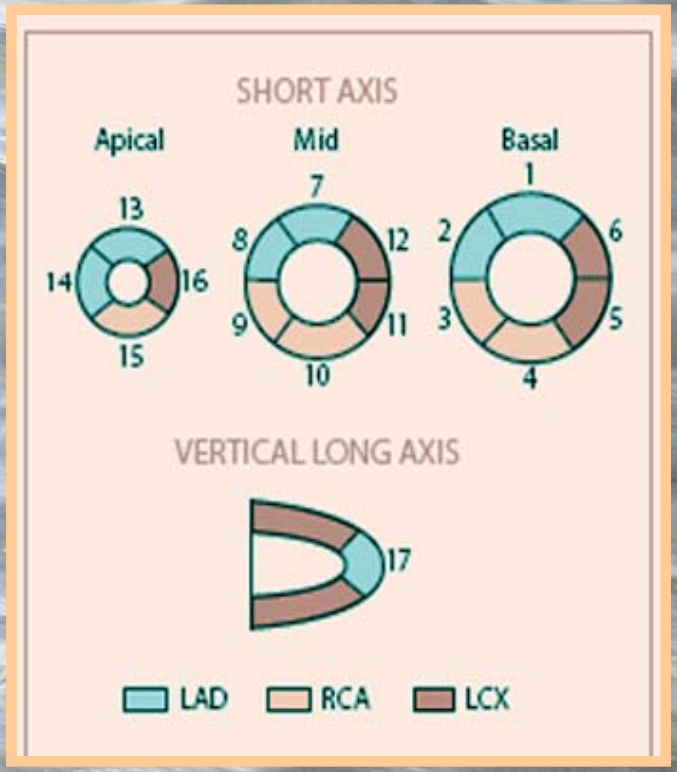
Summed Scores in Semi-quantitative measures in Nuclear Cardiology

Some of the important semiquantitative measures include
summed stress score (SSS),
summed rest score (SRS),
summed difference score
(**SDS=SSS – SRS;** reversibility score).



Nuclear imaging studies, performed with gated SPECT, are analyzed not only visually but also by a number of semiquantitative measures.

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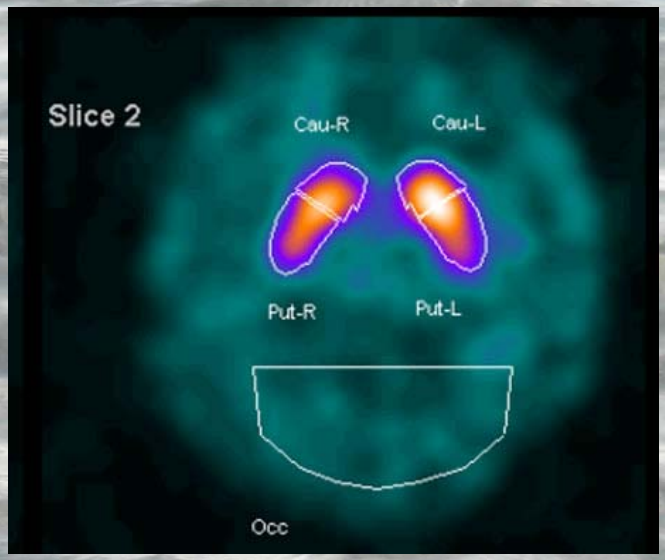
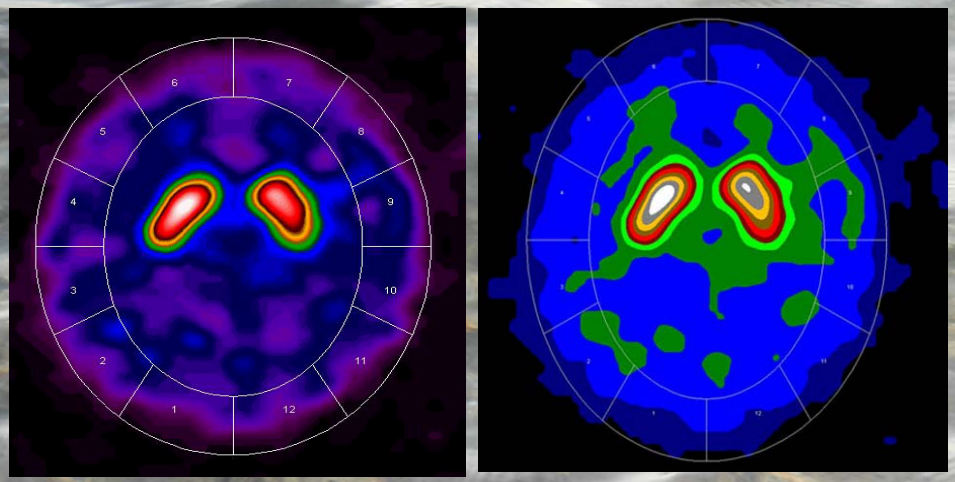
Ratios estimation of Stratium DatScan concentration



Ratios			
Striatum Total / Occ :			3.30
Caud-L / Occ :	3.50	\	
		>	3.37
Caud-R / Occ :	3.24	/	
Put-L / Occ :	3.46	\	
		>	3.23
Put-R / Occ :	3.00	/	
Putamen / Nucleus Caudatus :			0.96
Striatum-L / Occ :			3.48
Striatum-R / Occ :			3.12



Segmentation and Isocontours

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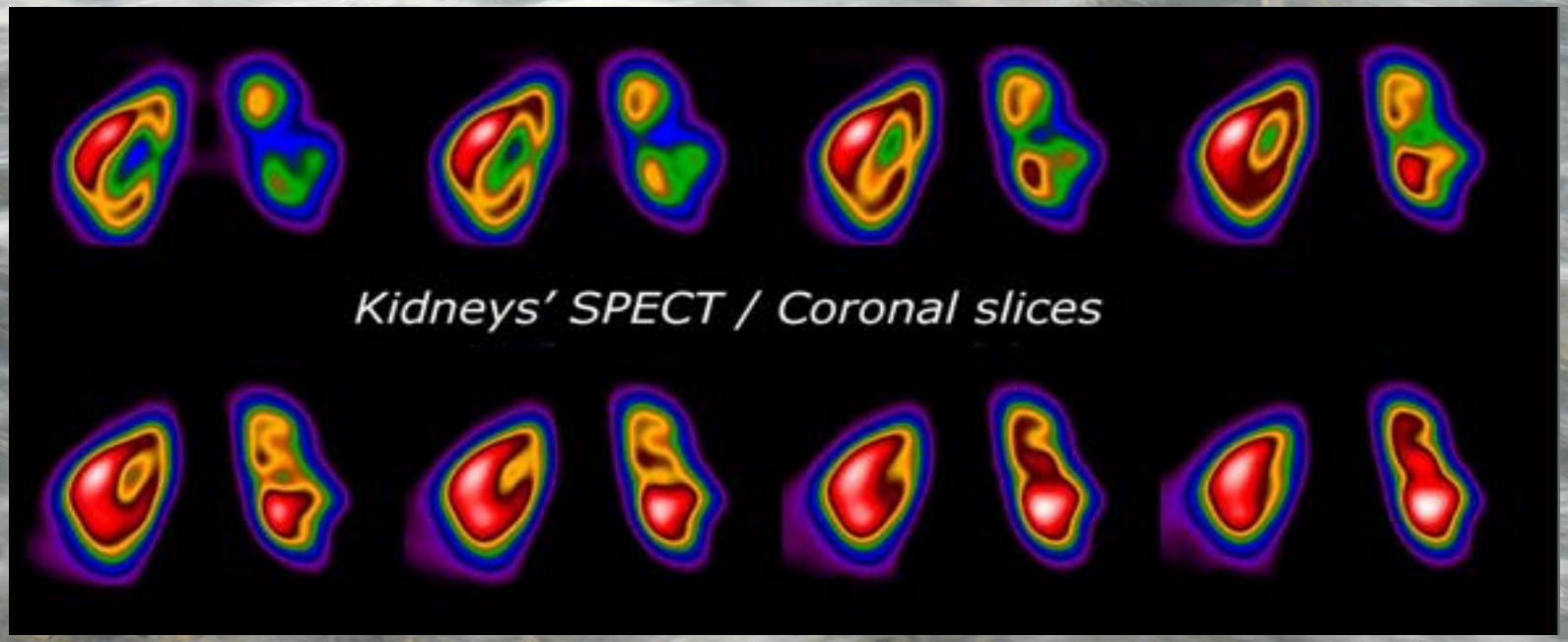
Segmentation

Segmentation is performed with algorithms that separate object and background pixels by comparing their intensity (counts) with the mean intensity of the region.

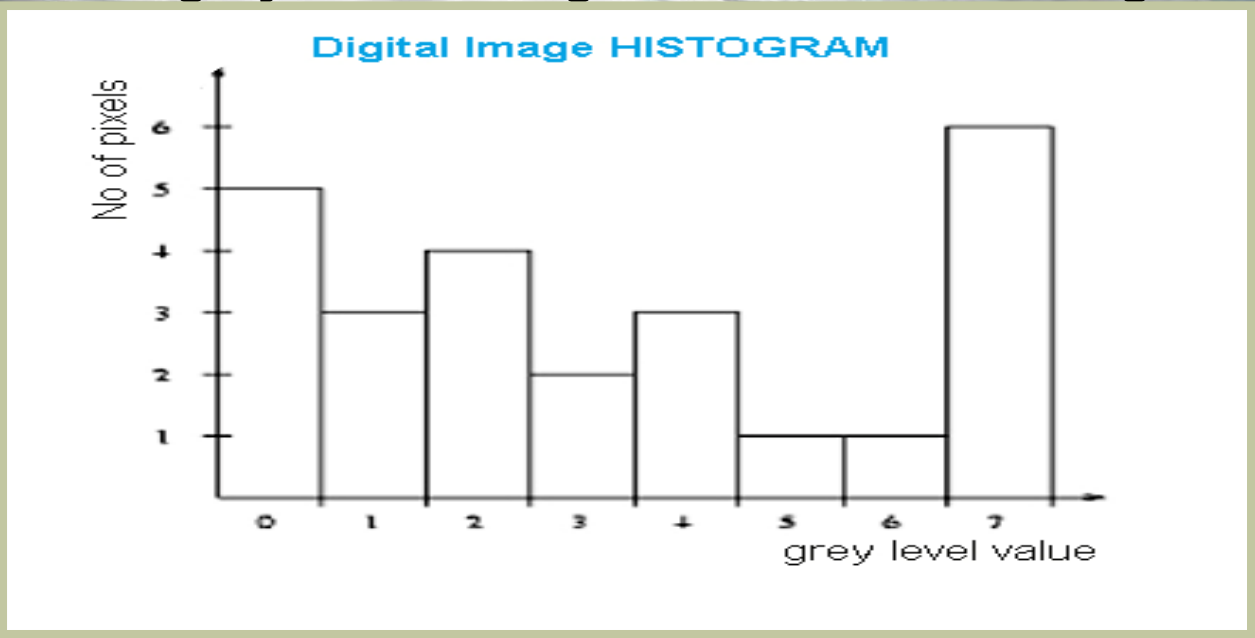
- A region of interest is roughly defined by the operator to include the slices of the organ to be reconstructed.



Thresholding

- is one of the simplest and popular techniques for image segmentation.

It can be performed based on global information that is grey level histogram of the entire image



- The main drawback of histogram-based region segmentation is that histogram provides no spatial information.

Grey level histograms analysis has been proven a suitable technique for thresholding

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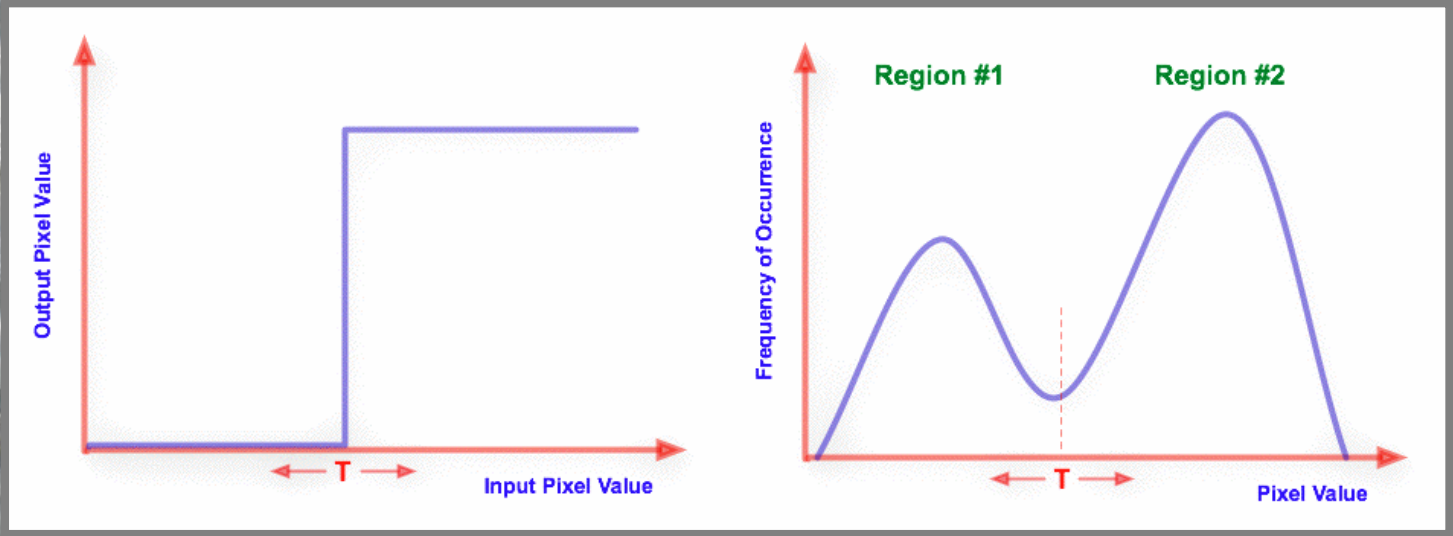
- Region thresholding exploits the fact that pixels close to each other have similar grey values.

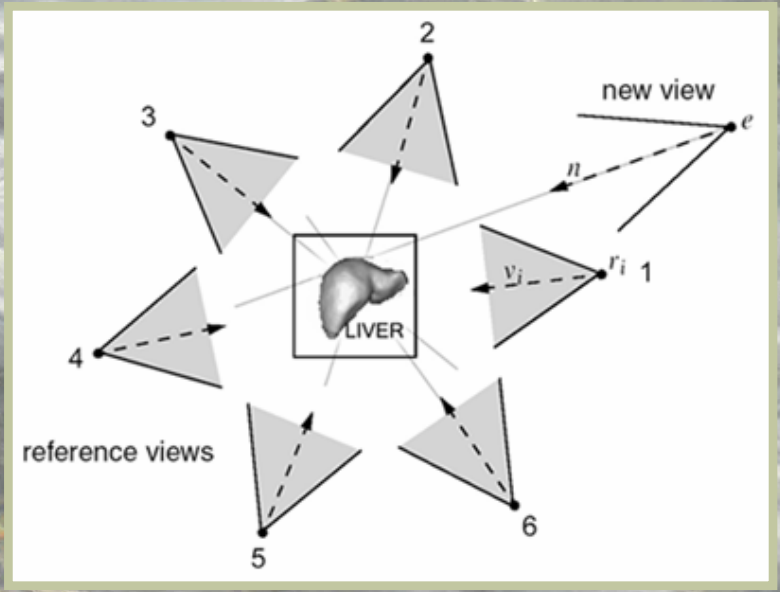
- **The main assumption of this approach is that regions are nearly constant in image intensity**



The threshold has to be adapted for each case as it is dependent on the size of the organ and the contrast of the reconstructed SPECT slices.

3D SPECT organ volume/

Image segmentation defines the borders of the organ and allows volume measurements by counting the voxels



Gradient

INTERPOLATION

Reference Views will contribute to the interpolated new view

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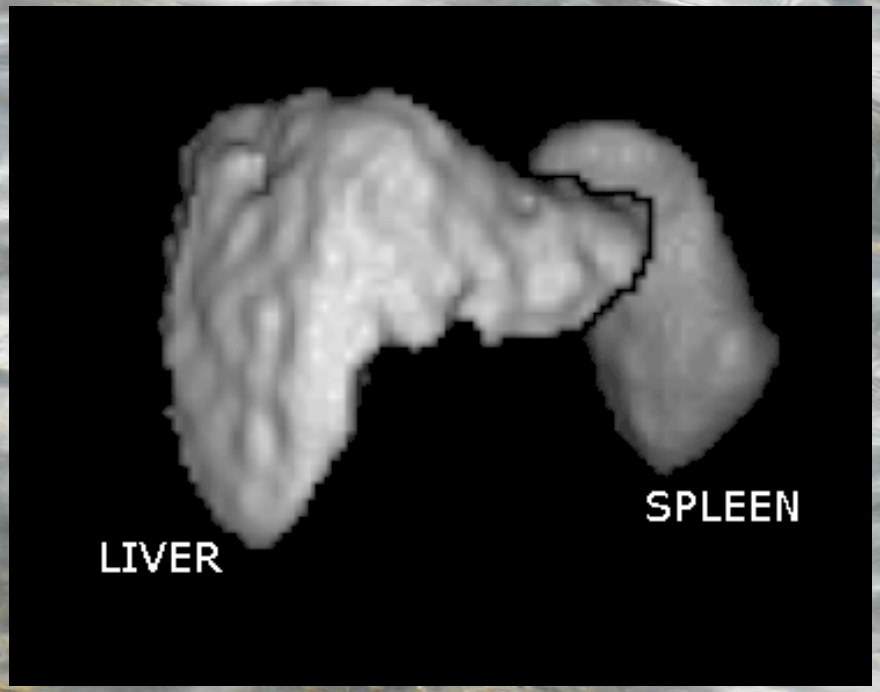
•The gradient shading is used to add shading to the 3D reconstructed image.
Gradient shading enhances the display of surface detail.



Discarding high gradient pixels close to edges improves the reconstructed image.

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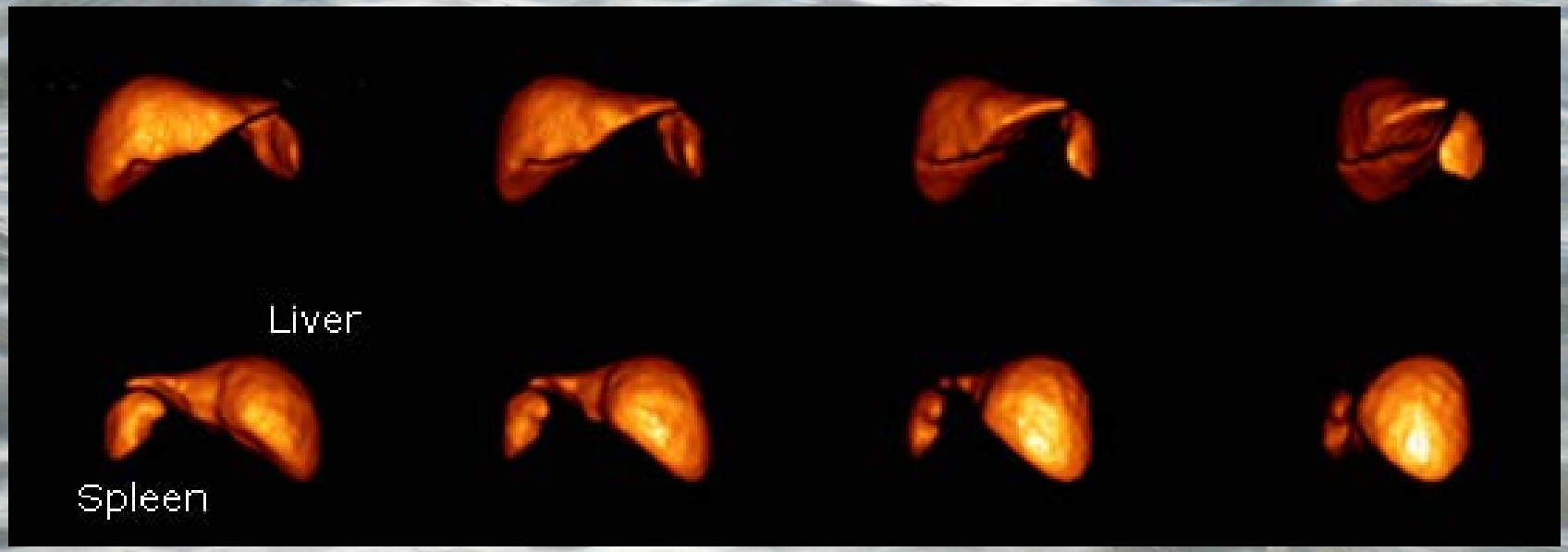

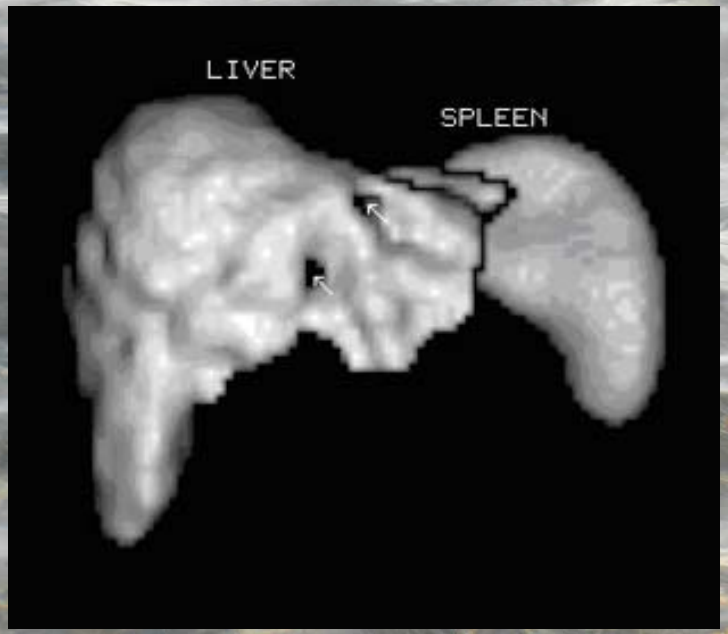

3D volume at different angle views

Liver 3D surface images

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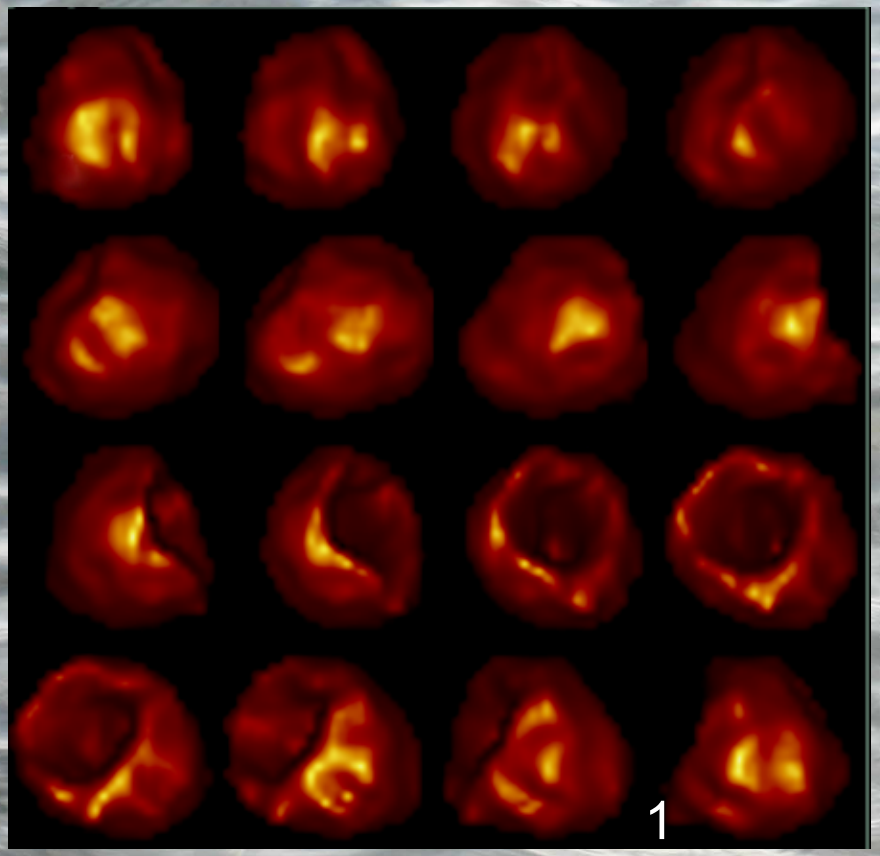

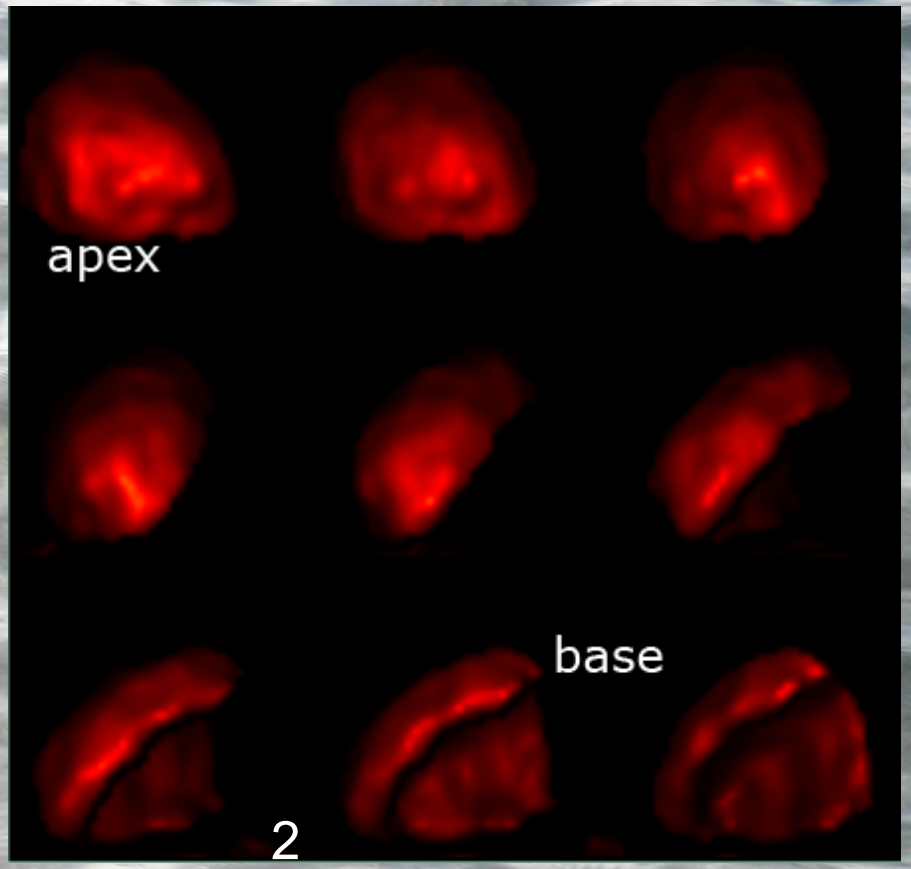

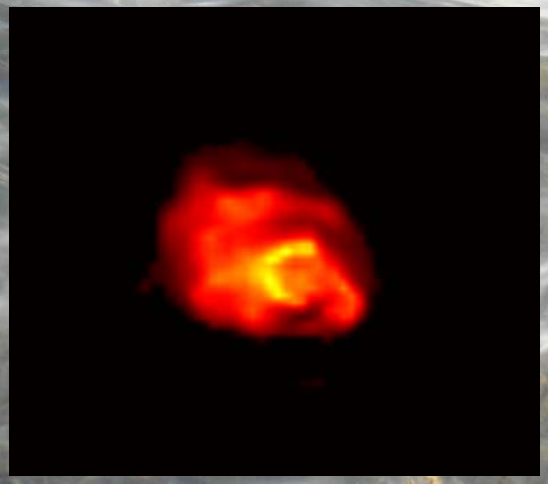

Myocardium 3D Volume at various angle views

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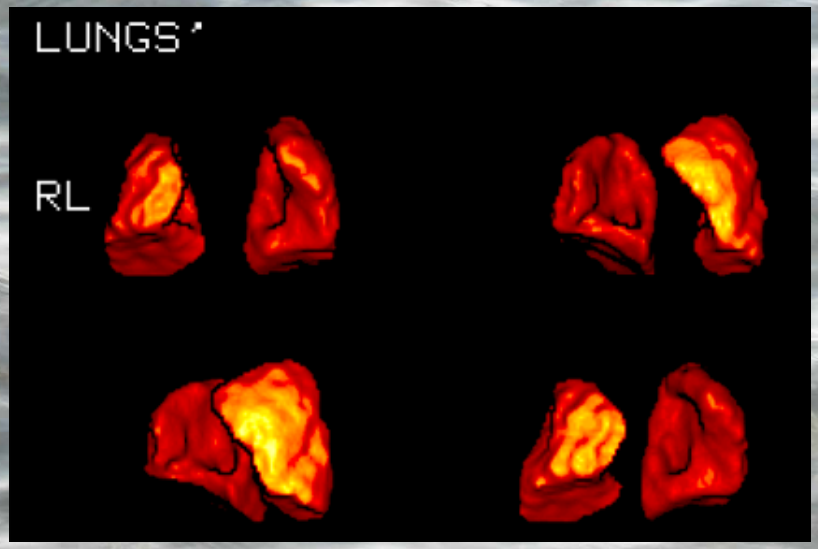

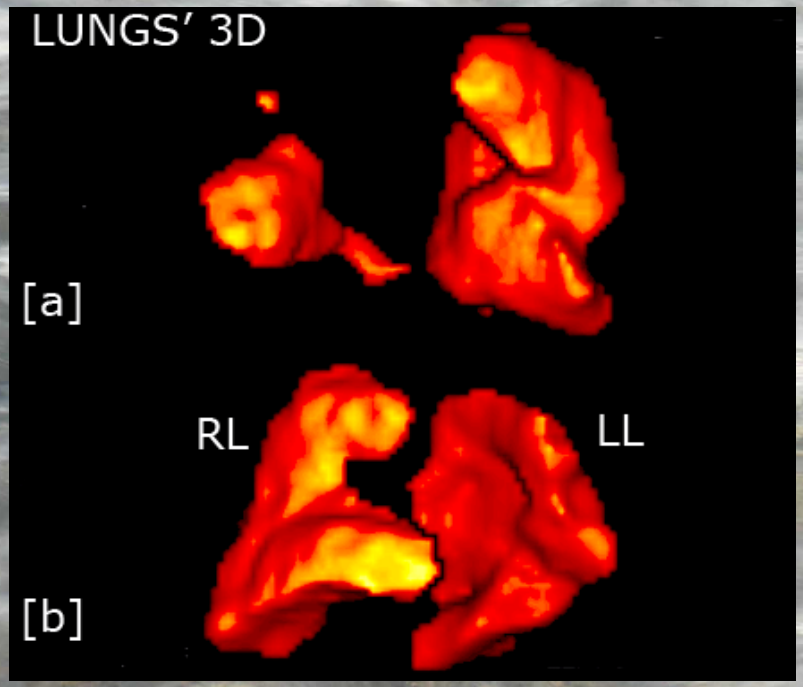

Normal 3D Lungs perfusion at 4 angle views

[a] το [b] 2 weeks time elapsed

Profound recovery

Quantitative evaluation

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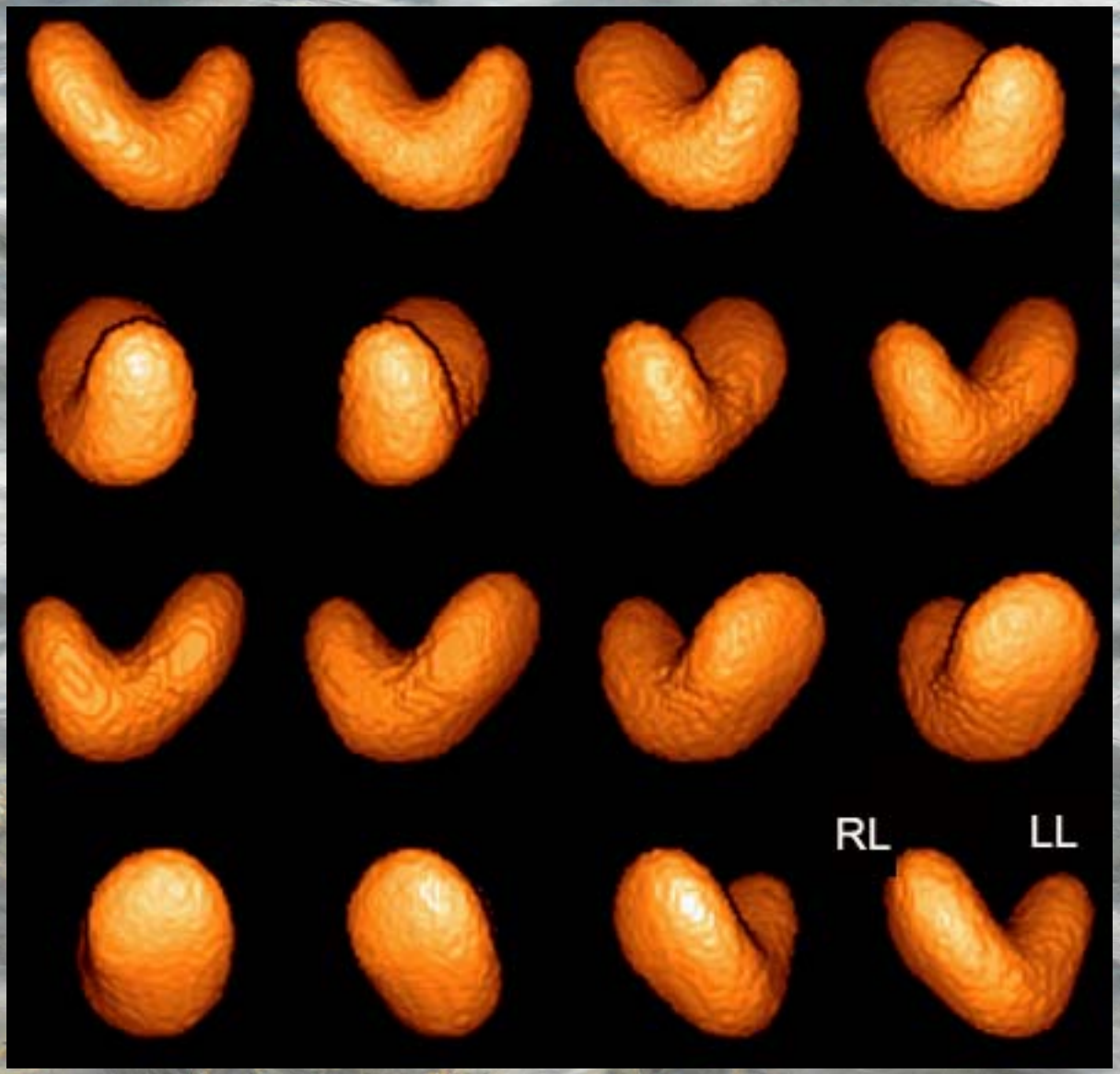
Normal 3D Thyroid gland 16 angle views



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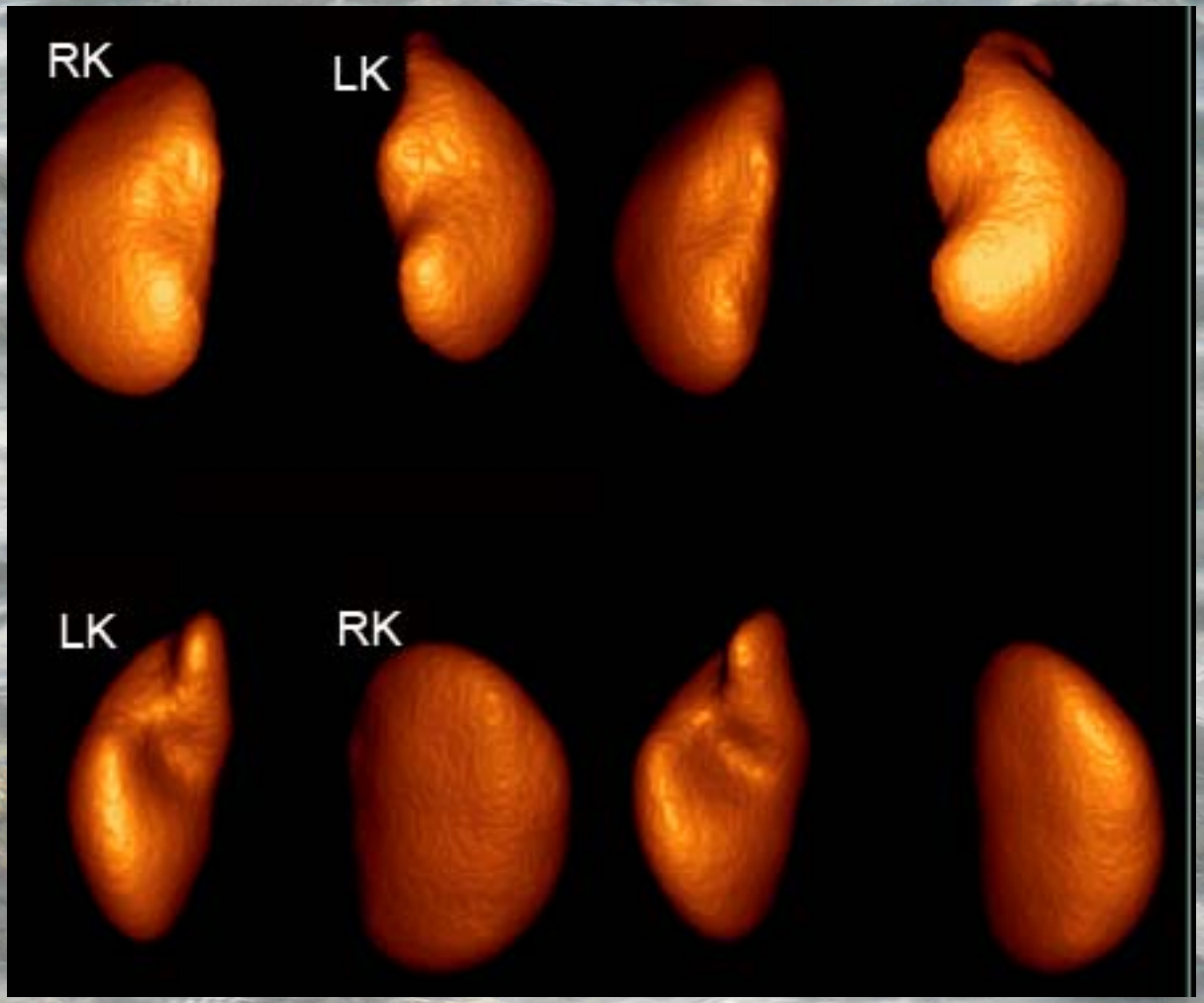
3D kidneys' imaging/ diagnostic information



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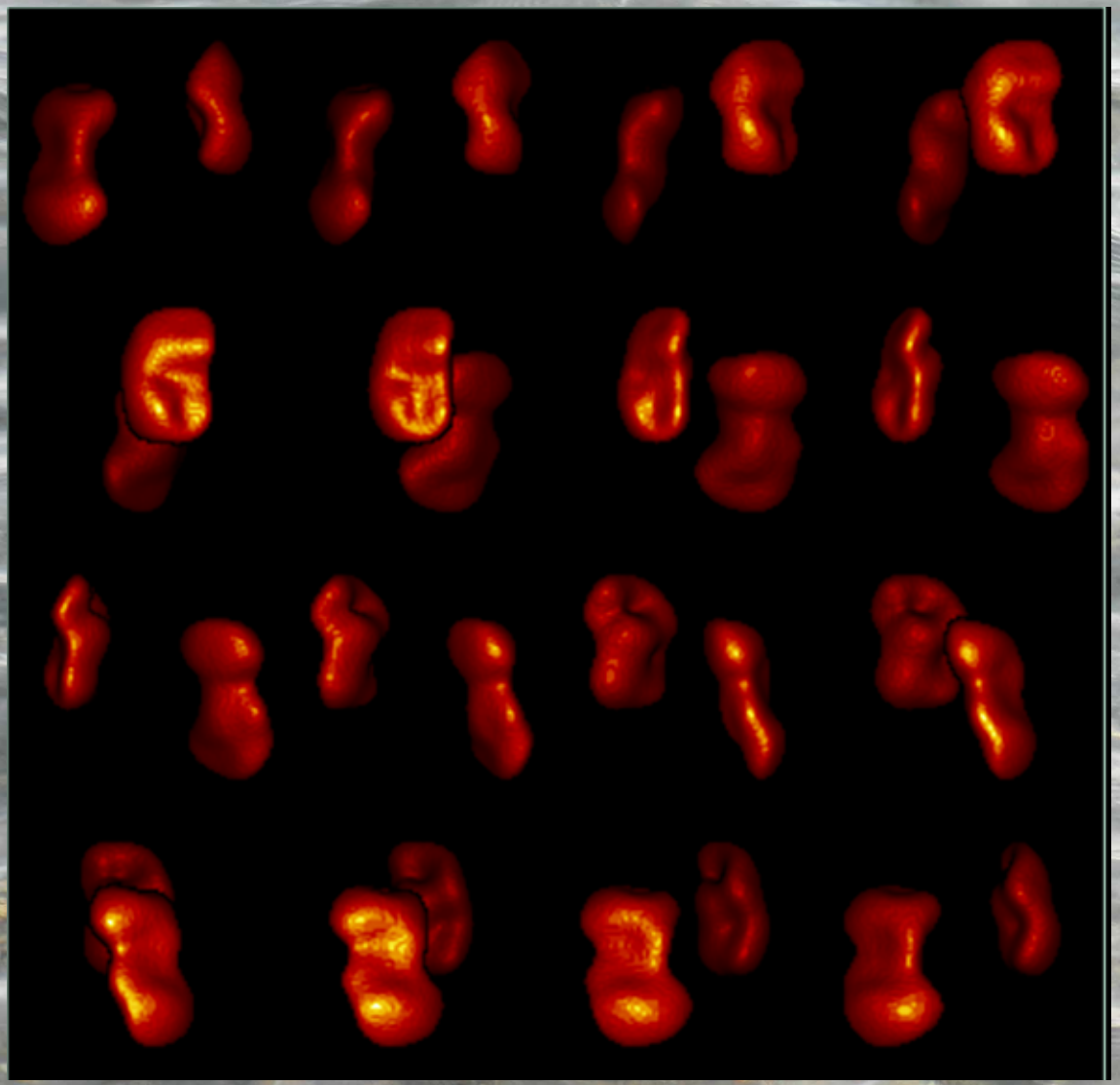
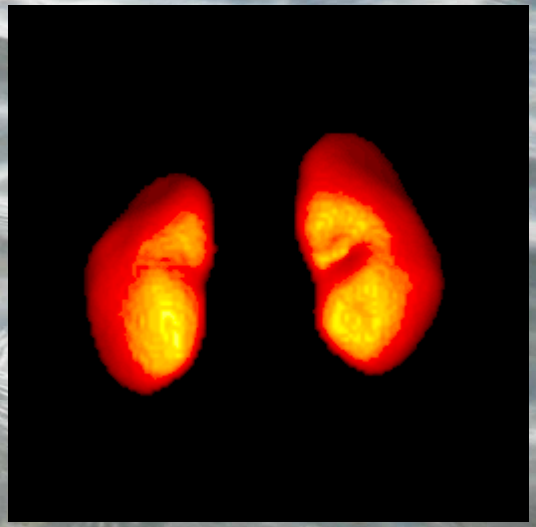
3D renal imaging by SPECT





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Hybrid systems

Computed tomography [CT] and single photon emission tomography [SPECT] differ in what each evaluates- anatomy for one and physiology for the other-

Hybrid systems of SPECT and CT are available allowing the combined assessment of anatomy and function, linking the anatomic richness of CT and the functional importance of SPECT.

fused SPECT/CT image / focal lesions

SPECT/CT is expected to lead to even further advances

but by decreasing the CT absorbed dose cost

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SPECT IMAGING

We sail for

Future improvement of 3D representation-quantification- texture classification by SPECT imaging

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