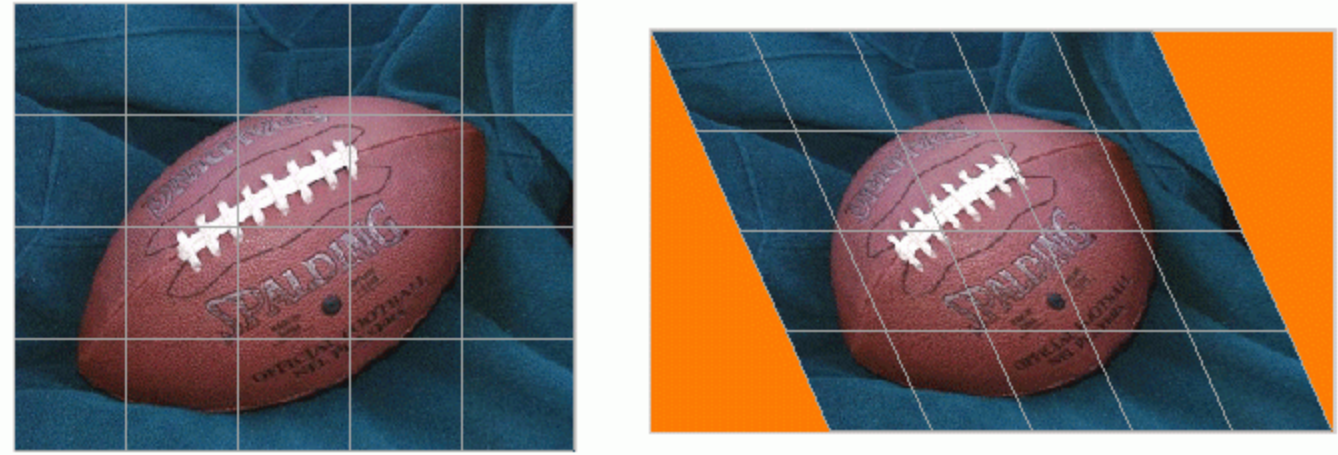
Technical aspects of SPECT and SPECT-CT

John Buscombe



What does the clinician need to know?

- *For SPECT*
  - What factors affect SPECT
  - How those factors should be sought
  - Looking for artefacts
- *For SPECT-CT*
  - Issues of registration

Factors that effect SPECT

- *Uniformity*
  - CFOV <2.5% variation in uniformity (extrinsic)
  - Should be tested by flood source
  - Intrinsic uniformity done with point source and no collimator
- *Centre of rotation*
- *Linerarity*
- *Energy correction maps (for different isotopes)*
- *Using the correct collimator*
- *SPECT resolution*

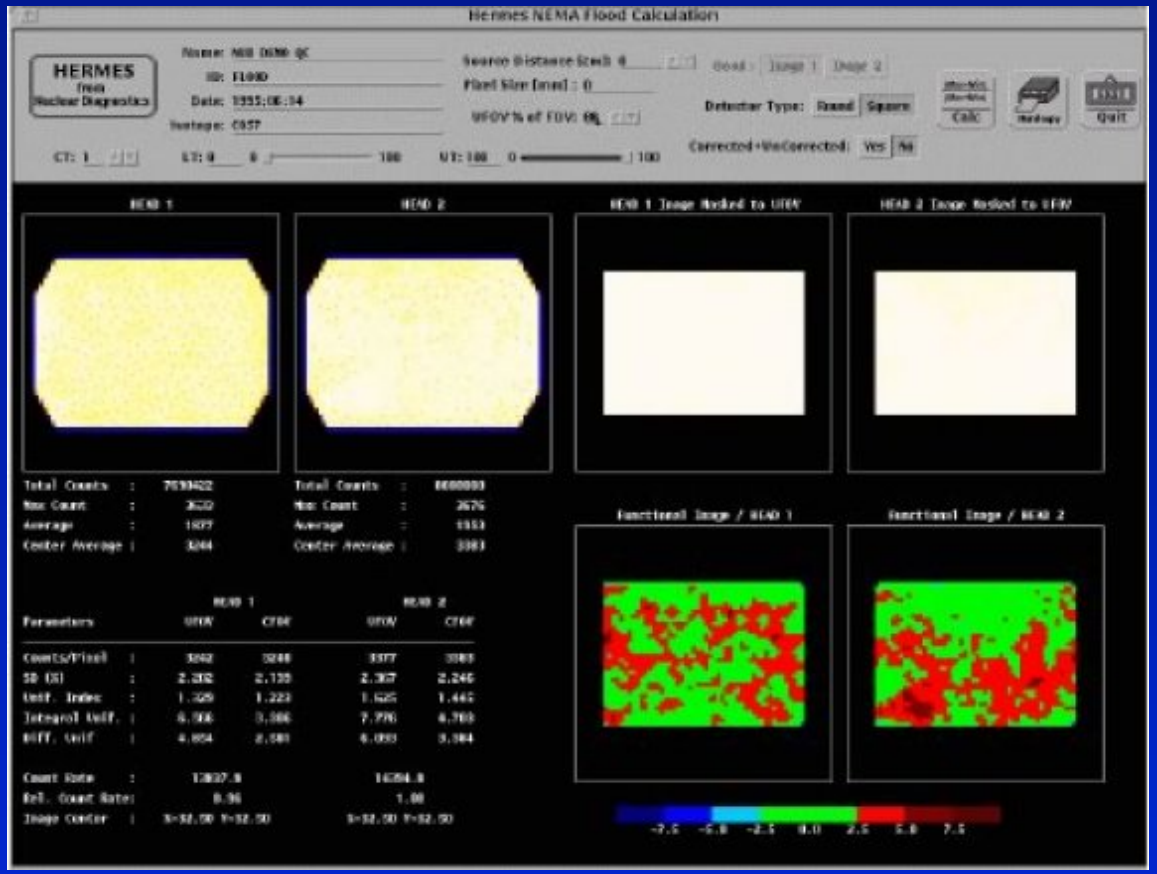
Needs a QC programme

- *Typical programme*
- *Daily*
  - Flood for uniformity
- *Monthly*
  - COR
  - Linearity
- *3 Monthly*
  - Flood corrections for less used isotopes
  - Resolution

Uniformity

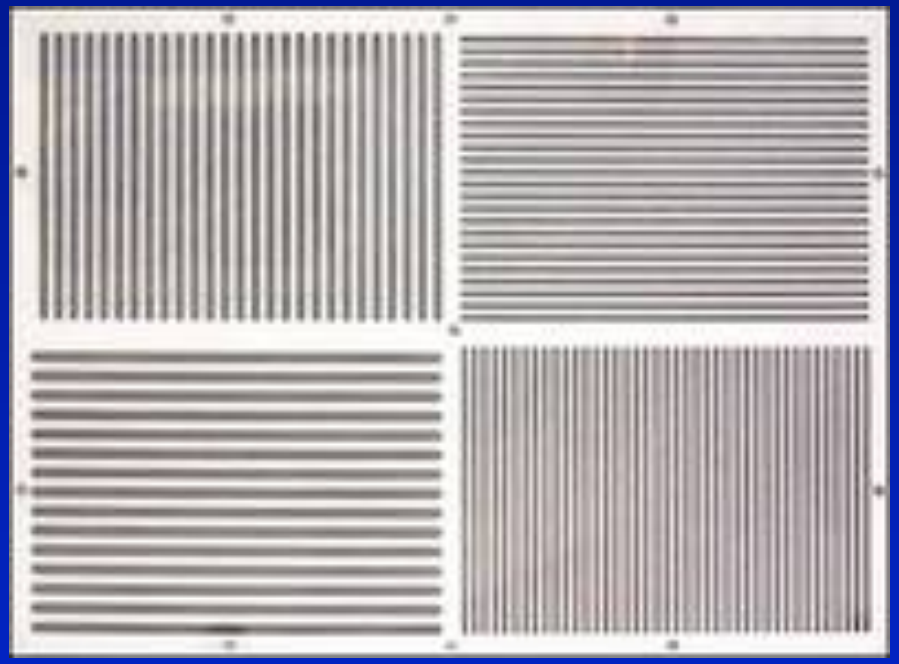
Note flood tank on gamma camera

Uniformity


Hermes NEMA Flood Calculation
HERMES
from
Nuclear Diagnostics
Calc
Quit
HEAD 1
HEAD 2
HEAD 1 Image Masked to UFOV
HEAD 2 Image Masked to UFOV
Functional Image / HEAD 1
Functional Image / HEAD 2

What is wrong on this triple headed gamma camera?

Linearity

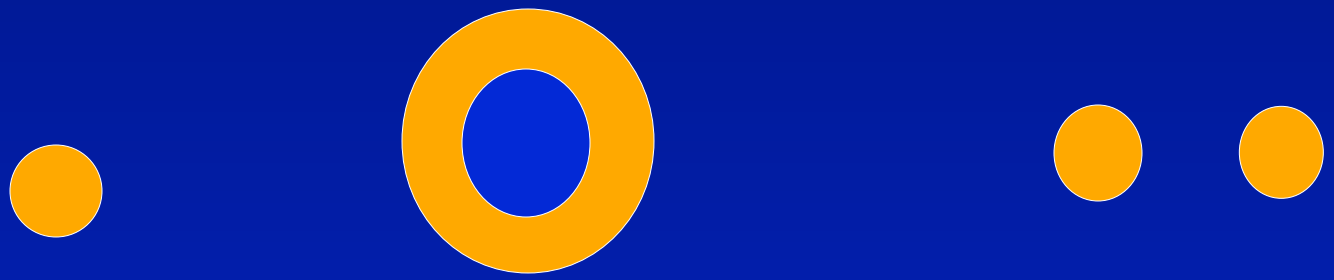


Tungsten cut out shield used with flood tank

COR

- *Use capillary tube of activity placed in the centre of rotation normally 10 cm long*
- *Acquire SPECT*
- *Reconstruct image*

COR

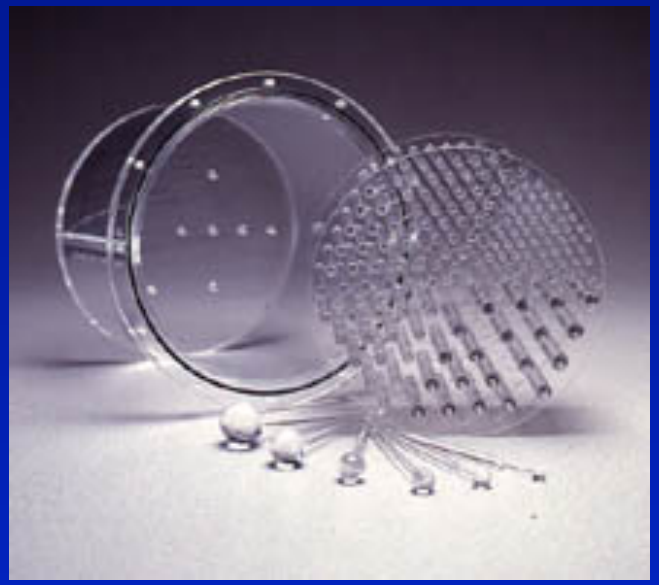


Perfect heads

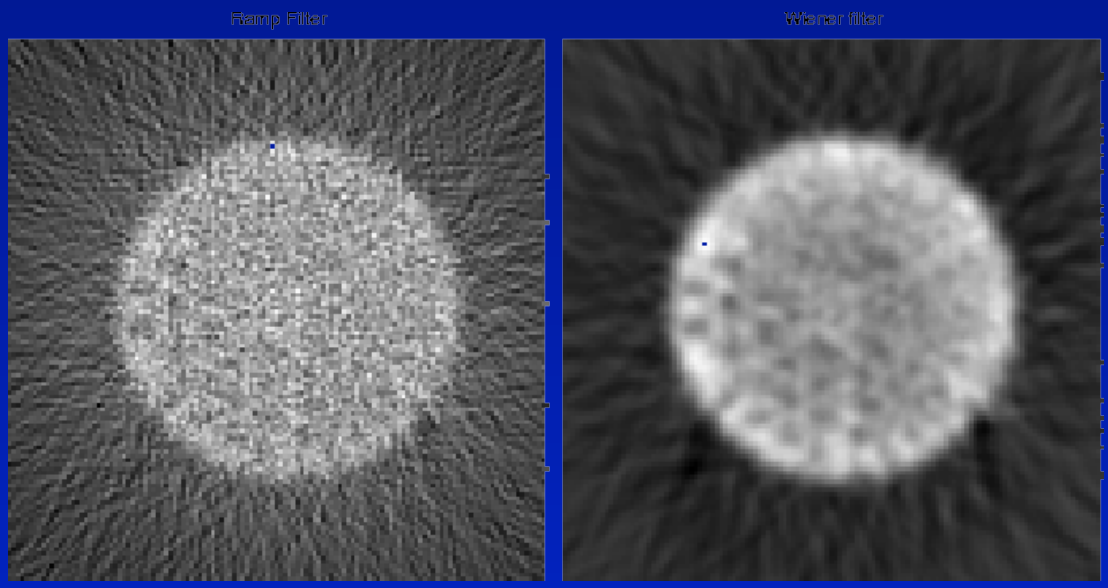
single head poor COR

2 heads both with good COR but misaligned

SPECT resolution



Jaszack SPECT phantom



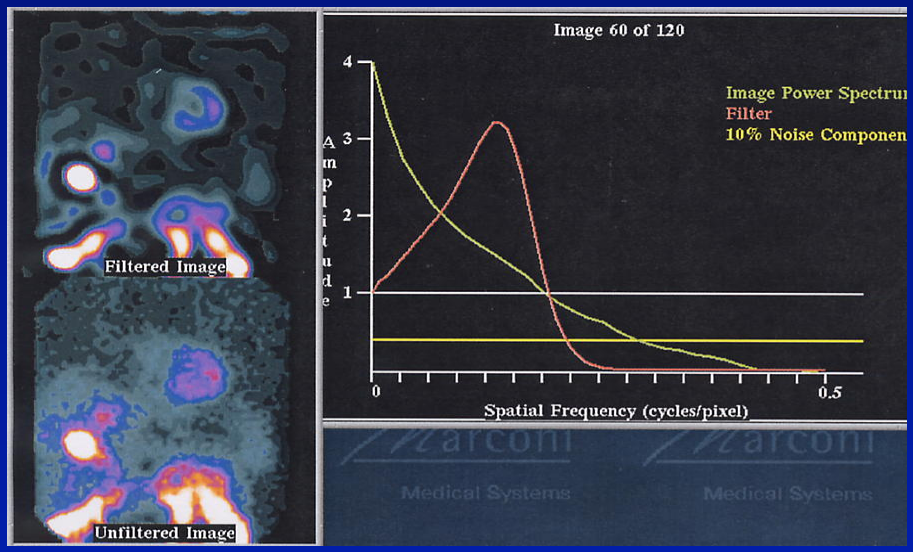
Images (filtered and unfiltered

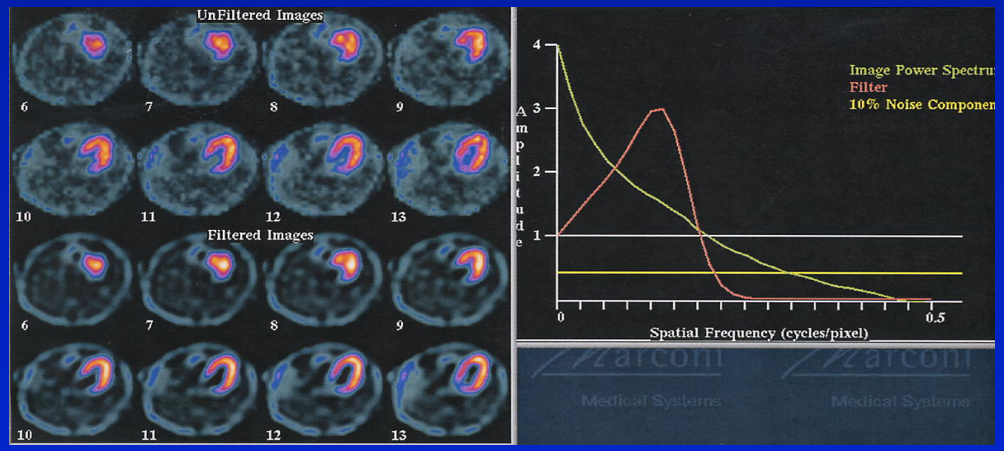
Then all you need to do

- *Reconstruct image correctly*
  - Back projection
  - Interative
- *Correct filtering*
  - Some filters more count dependent that others
  - Though called the same different manufacturers filters often very different

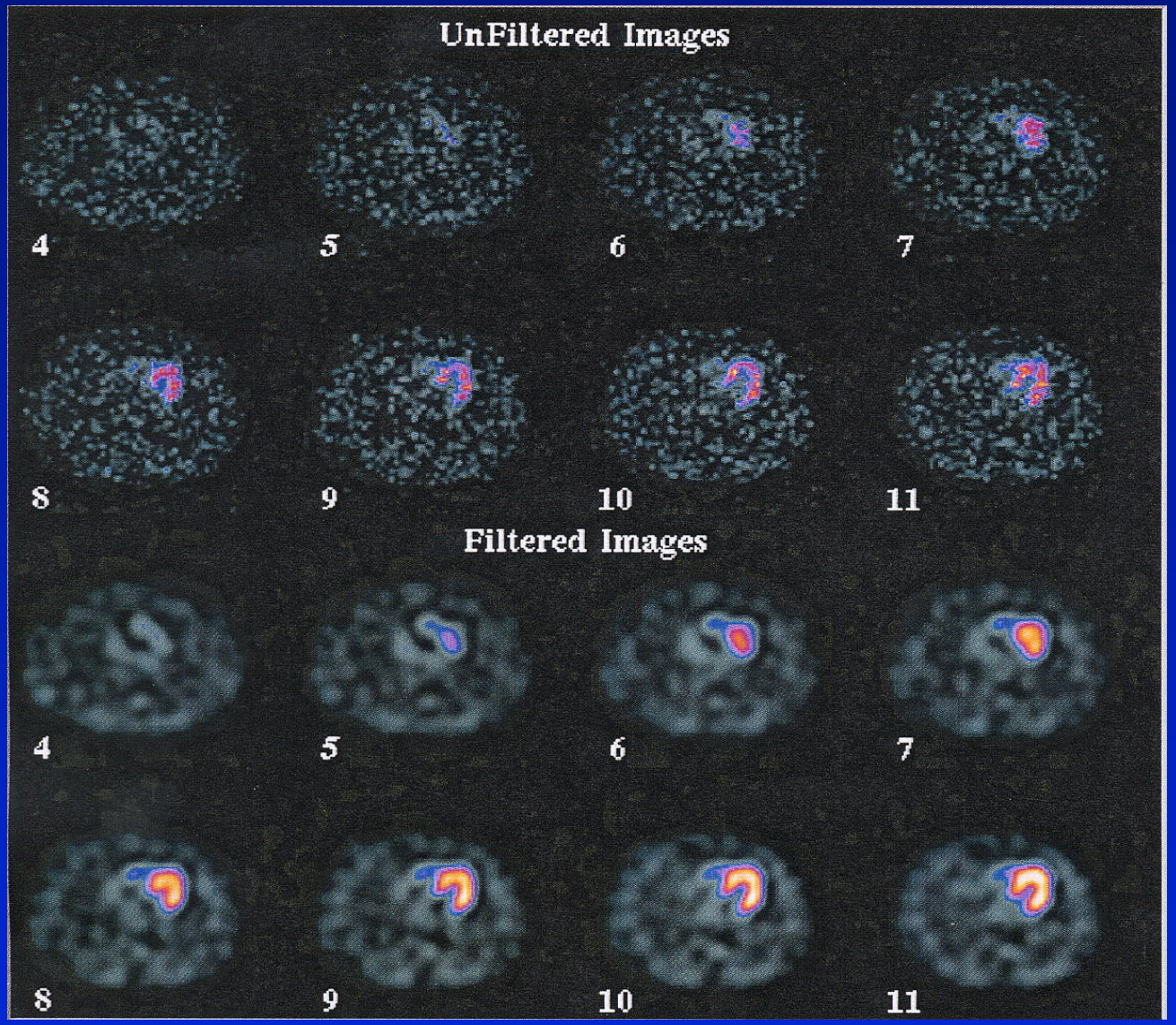
Filtering

- *Can use predefined protocols*
- *However filter count related*
- *Maybe best to use a manual filter*
- *Check images are not over filtered*

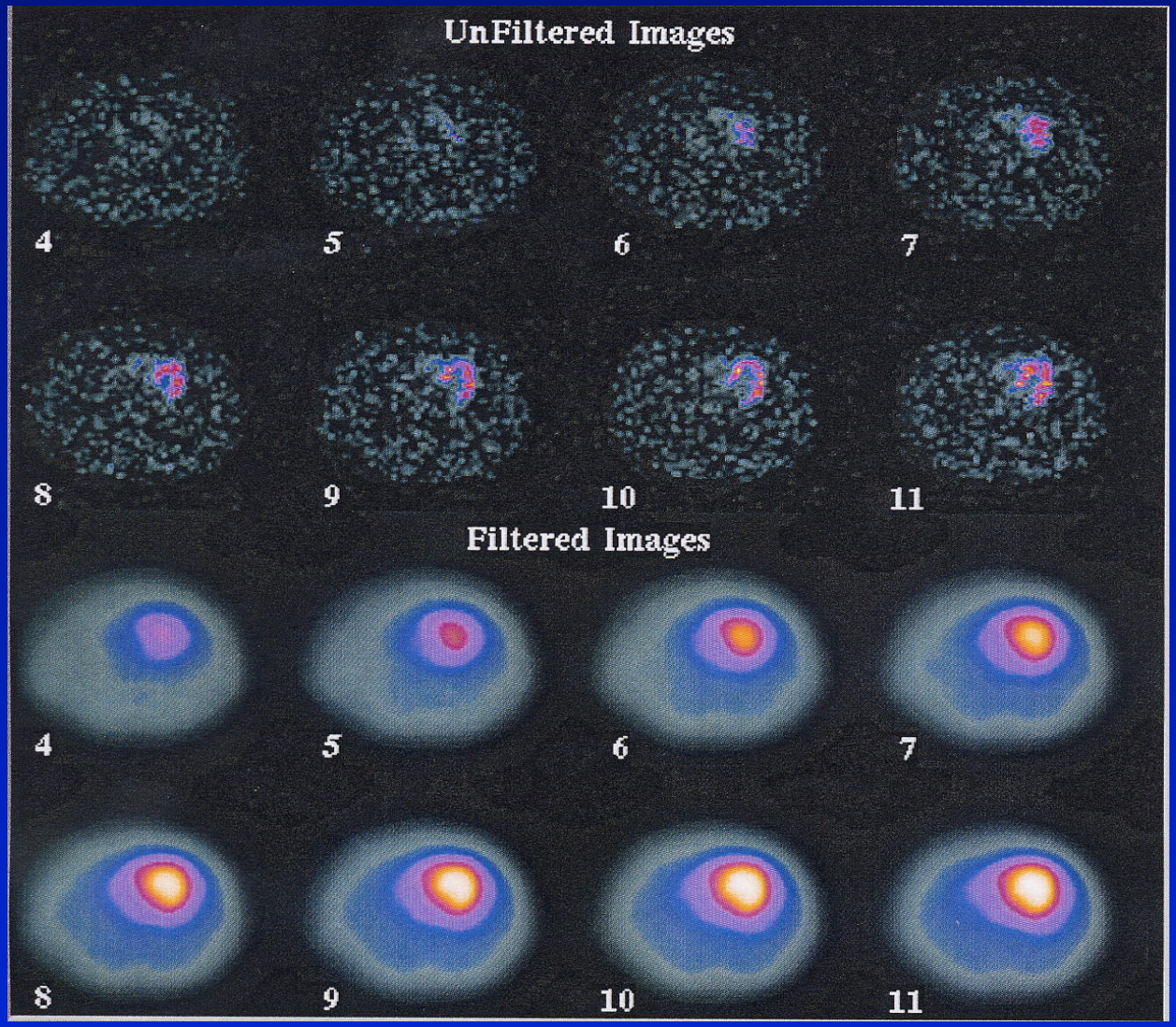




Post filtering-correct



Over smoothed



Over filtered

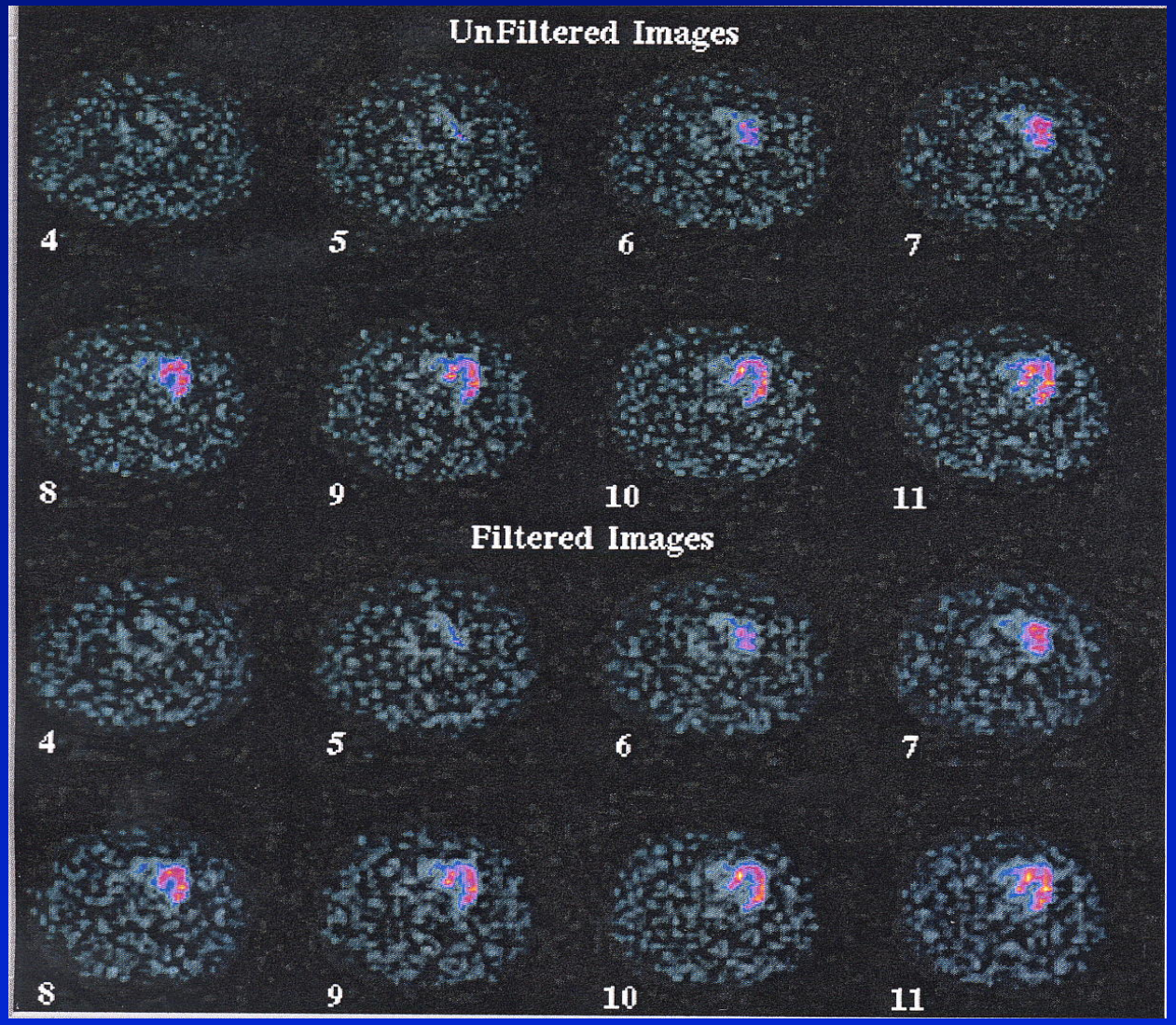


Image Fusion

Image Registration

- Process of spatially aligning images from the same or matching modalities
- CT/MR/NM

Image Registration

- Intra/Inter modality
- Two approaches
  - Dedicated dual modality hardware
  - Software algorithms

Why?

Allows:

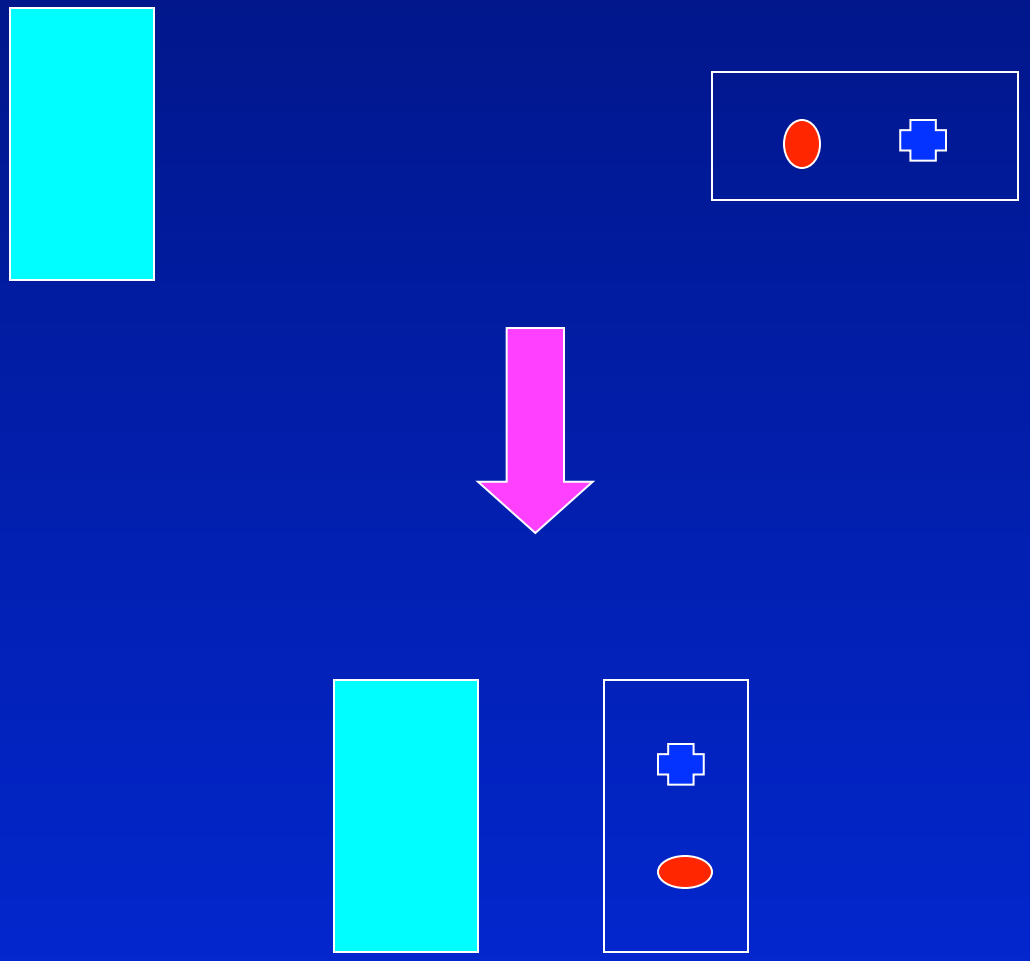
- Fusion of molecular and anatomical information
- Maximise potential of the complementary information
- Precise localisation of organs and lesions
- Comparison of studies performed at different times

Registration vs Fusion

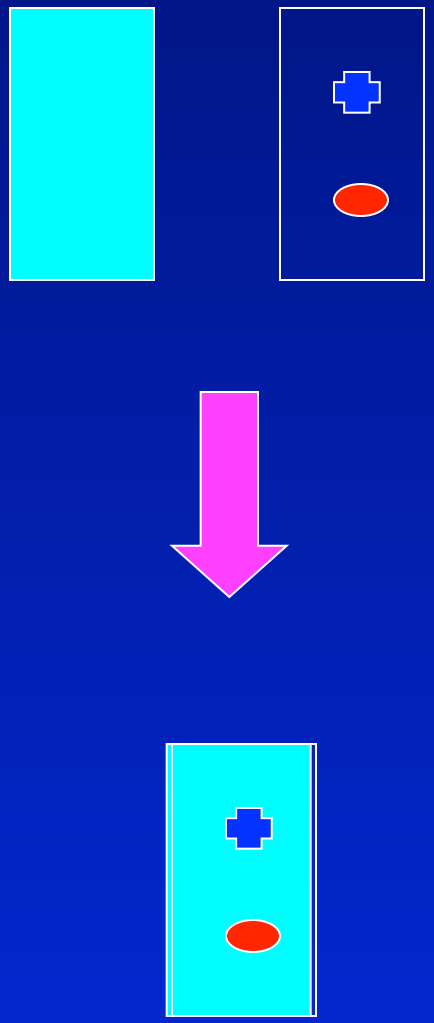
- Registration = Technical manipulations applied to align images

- Fusion = Use of the registered images; most often superimposed images in a single display

Registration



Fusion



How?

- Software used to identify the necessary transformation required, so that when it is applied to one study, the result is the best possible spatial alignment with another study
- Many different software packages available
- Many different ways to register images

Transformations

- Rigid (Linear)
  - position or orientation different between two image sets
  - simple translation or rotation required
  - used to register scans from the same patient at different times

Transformations

- Affine (Linear)

  - additional scaling/zooming and shearing

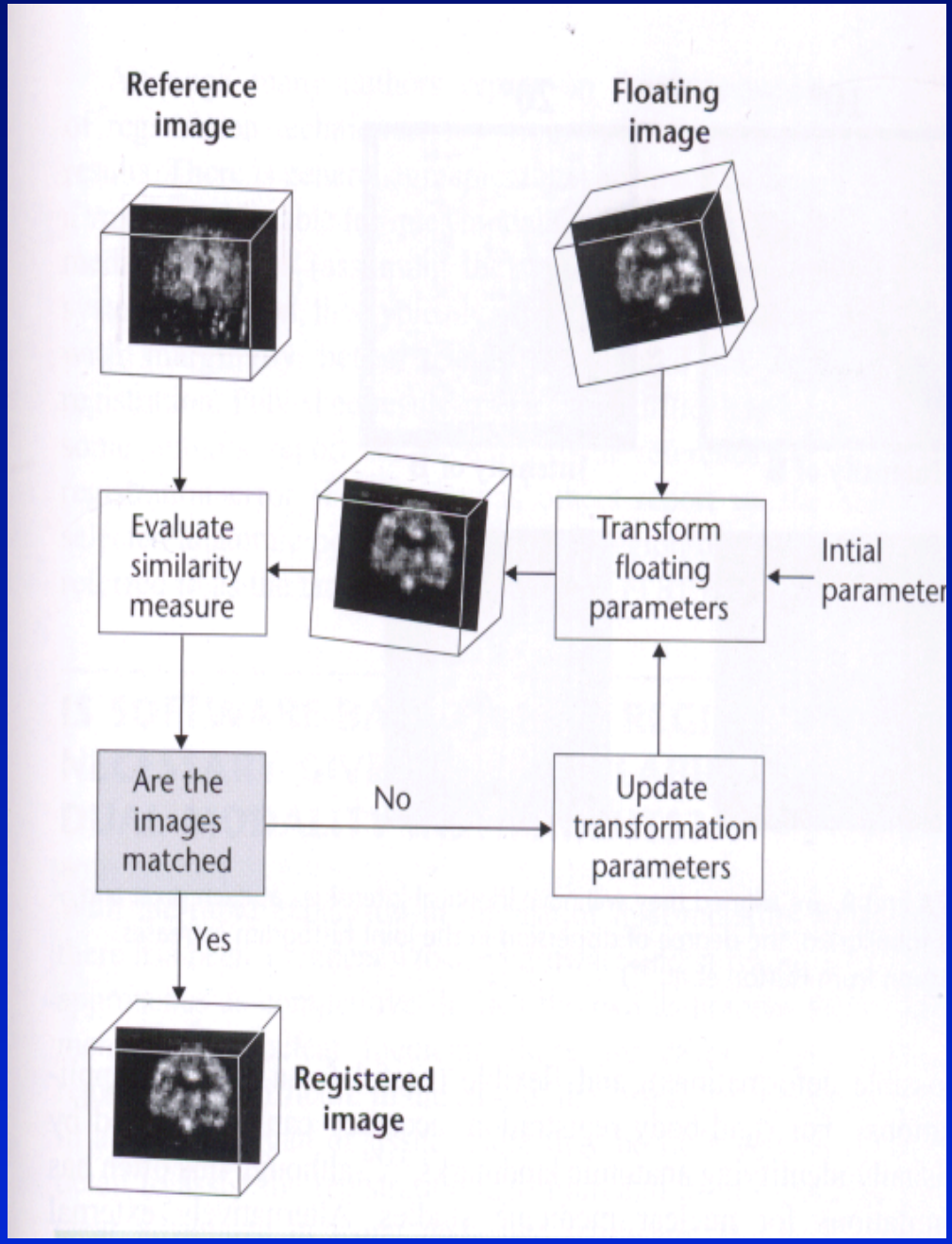
  - spatial transformation of one co-ordinate system (x,y,z) to another (u,v,w)

$$u = p_1x + p_2y + p_3z + p_4$$
$$v = p_5x + p_6y + p_7z + p_8$$
$$w = p_9x + p_{10}y + p_{11}z + p_{12}$$

Transformations

- Non-linear
  - usually applied after linear techniques
  - correct for differences in shape that cannot be accounted for by affine normalisation
  - warping of the image

- Initial guess at transformation parameters
- Floater reorientated
- Similarity compared
- Parameters updated
- Continued until preset termination point reached



Measures of Similarity

- Require a quantitative measure of alignment between the two images
- Similarity measure will reach a maximum when the images are most closely aligned
- ‘Best match’ ambiguous
- Large variety been proposed

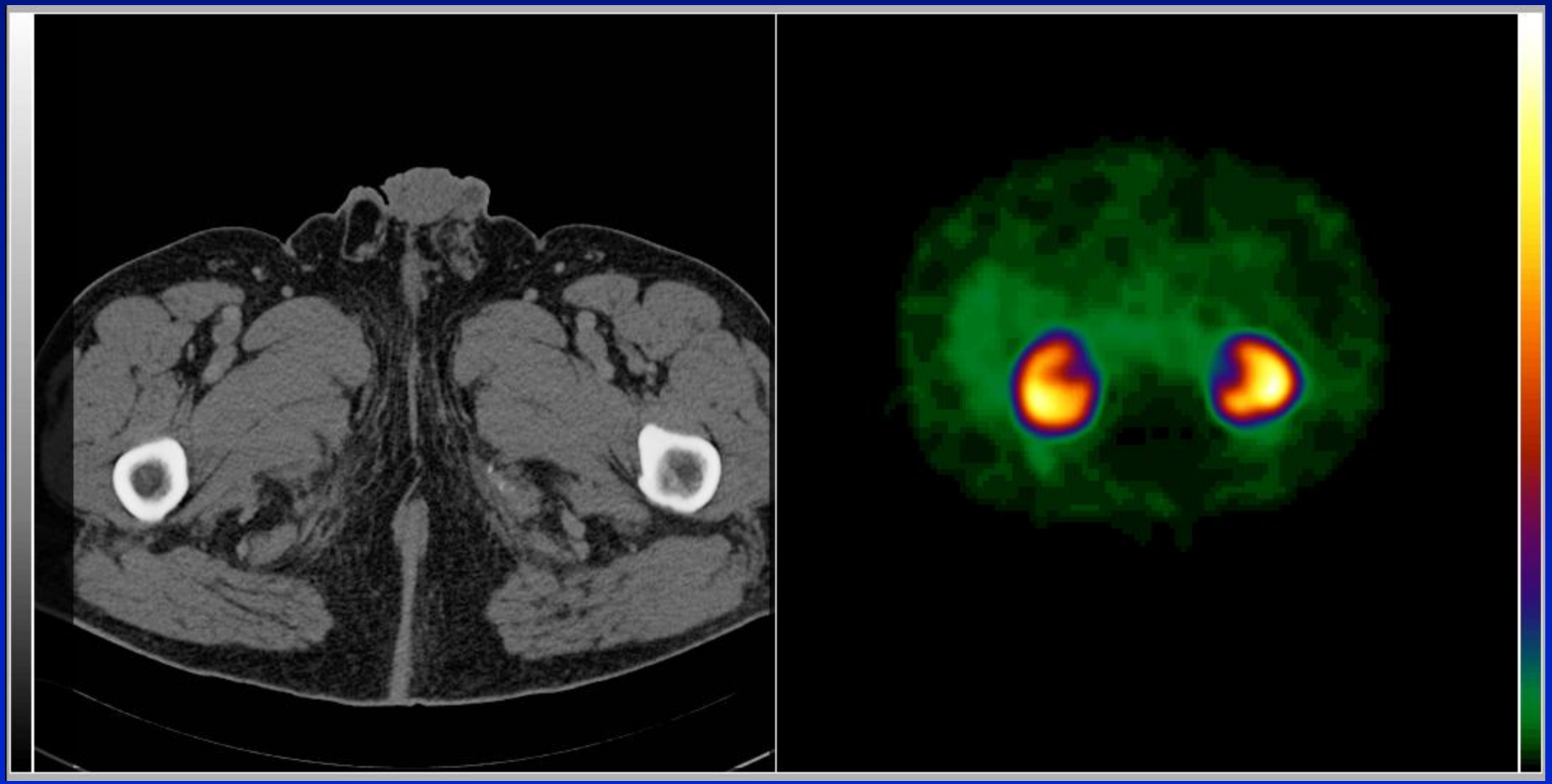
Measures of Similarity

- Point based methods
  - extrinsic markers (prospective)
  - intrinsic markers (retrospective)
- Comparison of voxel intensity values
- Edge/Surface based

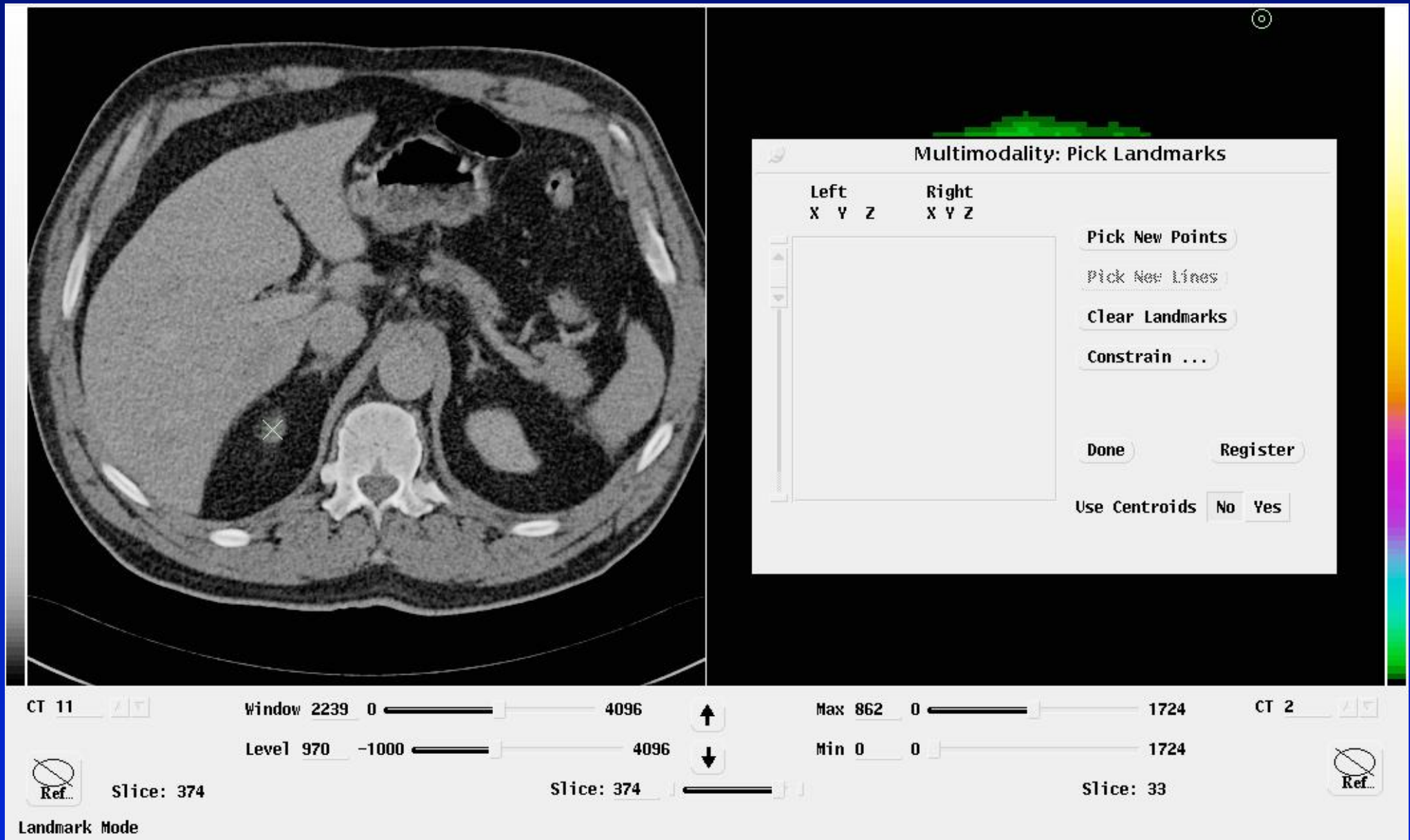
Wrist Registration

- Splint with cobalt markers
- UV sensitive
- Digital DP film
- Registered with bone scan

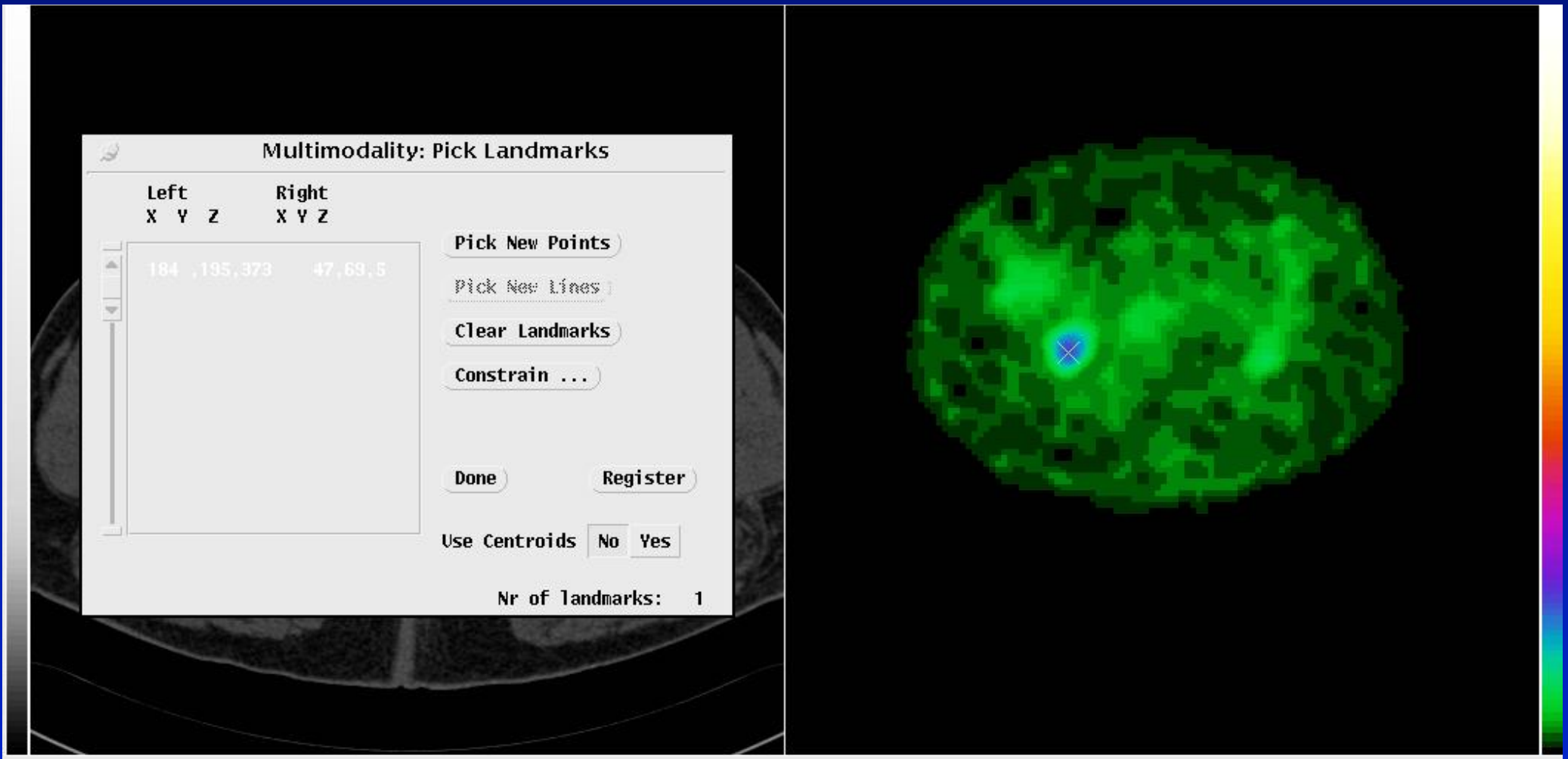
Intrinsic Markers



Intrinsic Markers



Intrinsic Markers



Layout of fused images

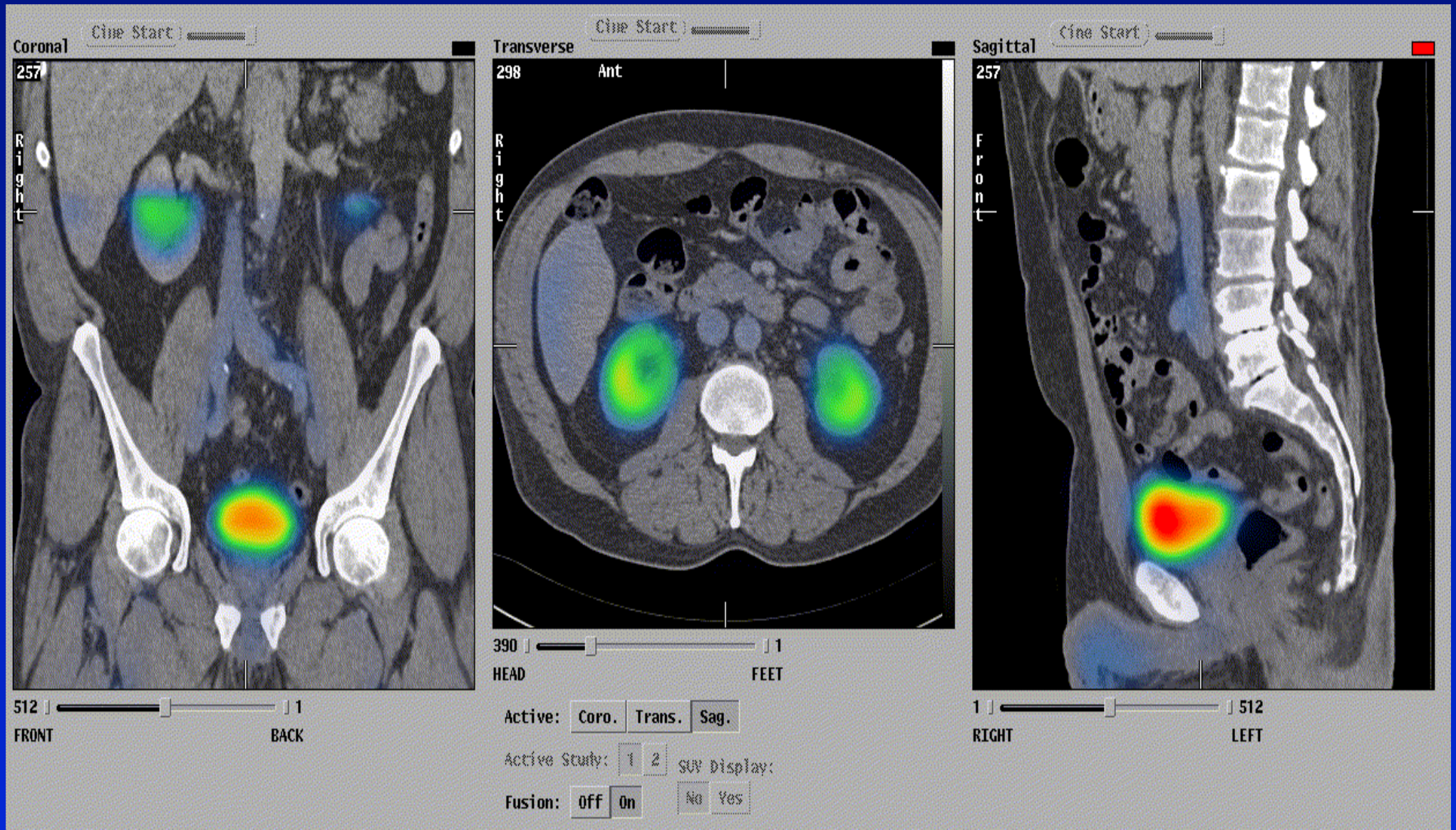


Image Display

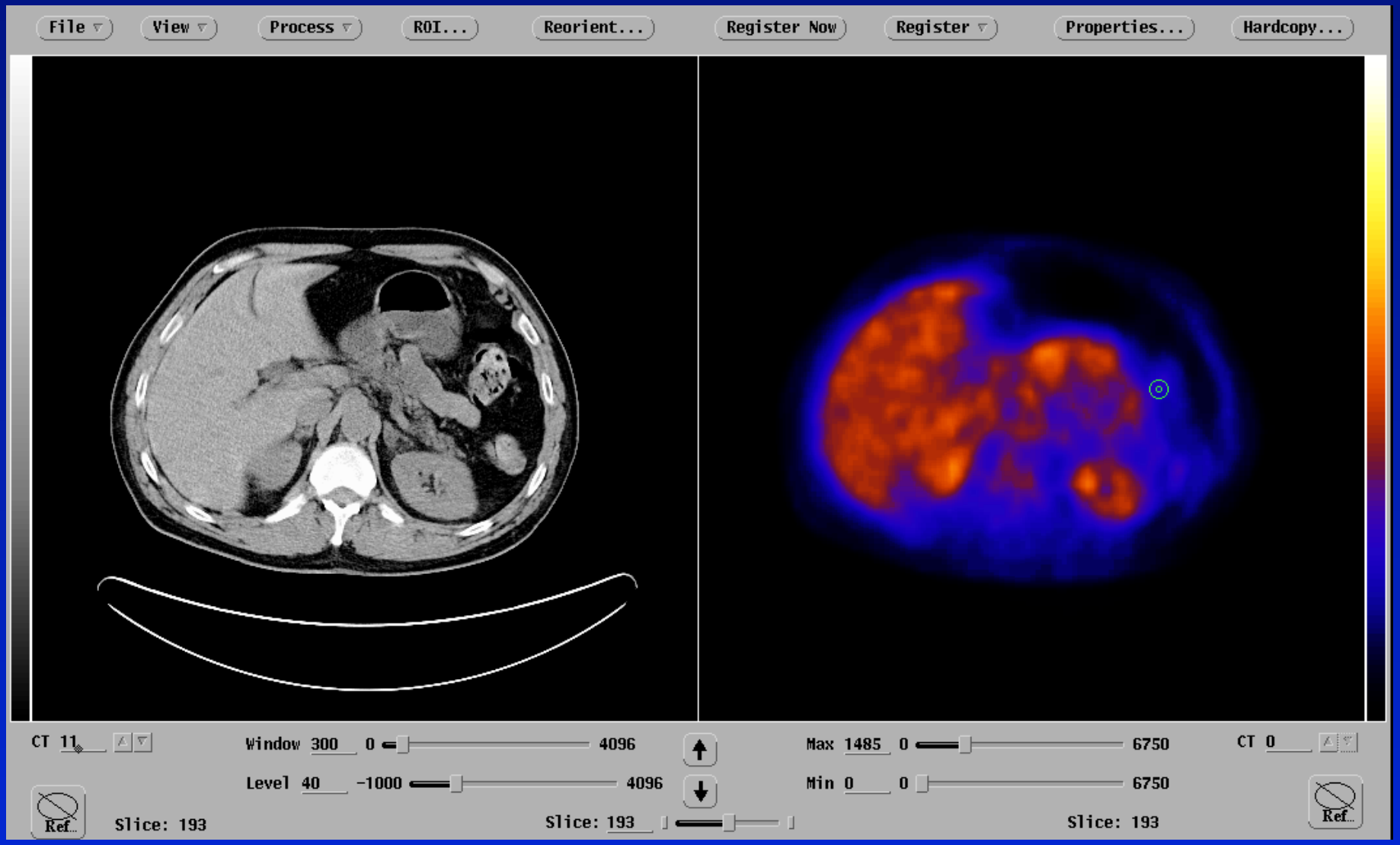
- Fusion Display
  - Grey scale for CT/MR
  - Colour for PET/SPECT
  - New colour values computed for each pixel, simulating the transparency effect
  - Artificial increase in the perceived intensity of colour images

Image Display

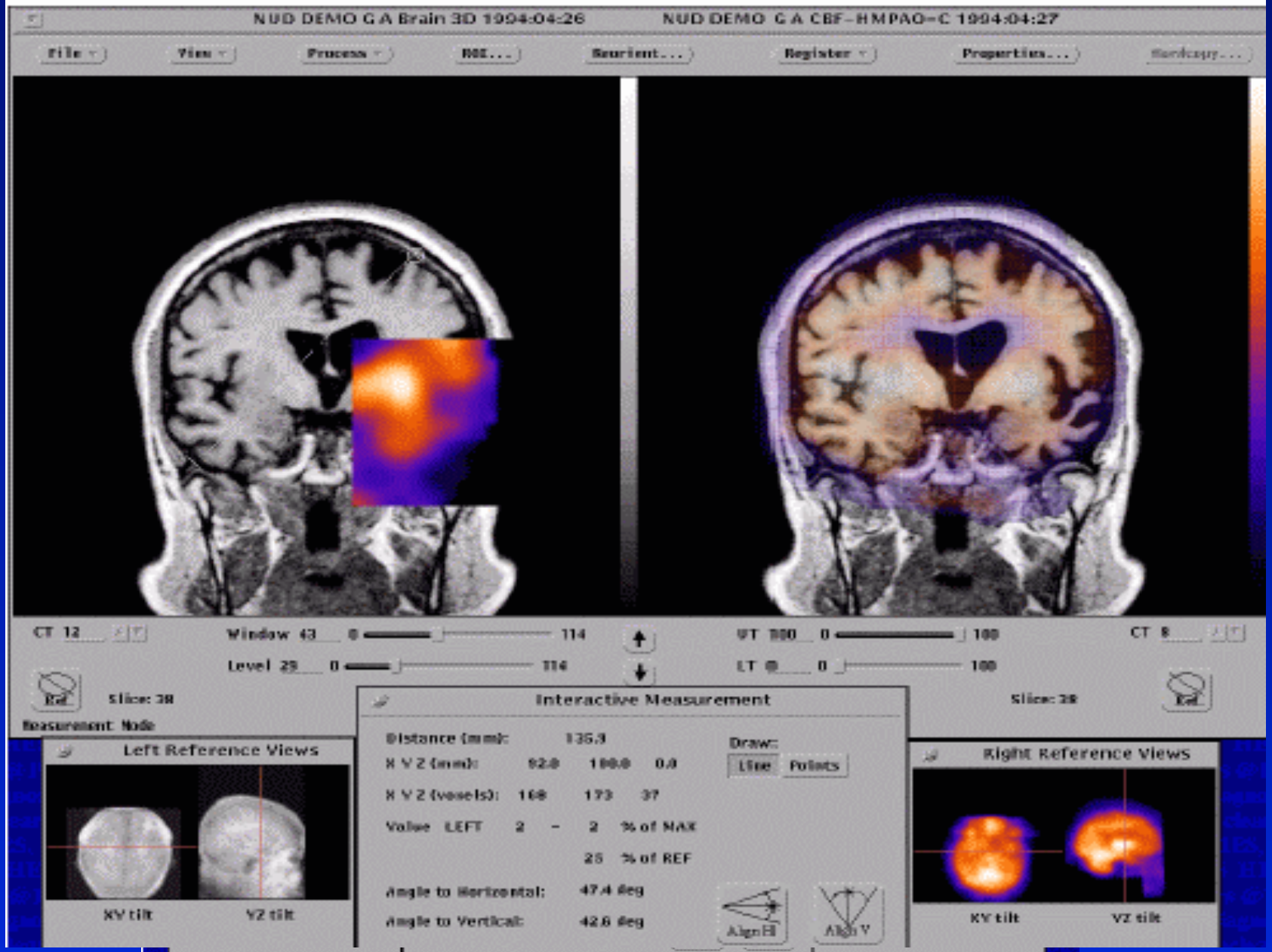
- Multimodality Display
  - Display both modalities side by side
  - Synchronized cursors displayed simultaneously on both images
  - Advantage no information lost

Fused Display

Multimodality Display

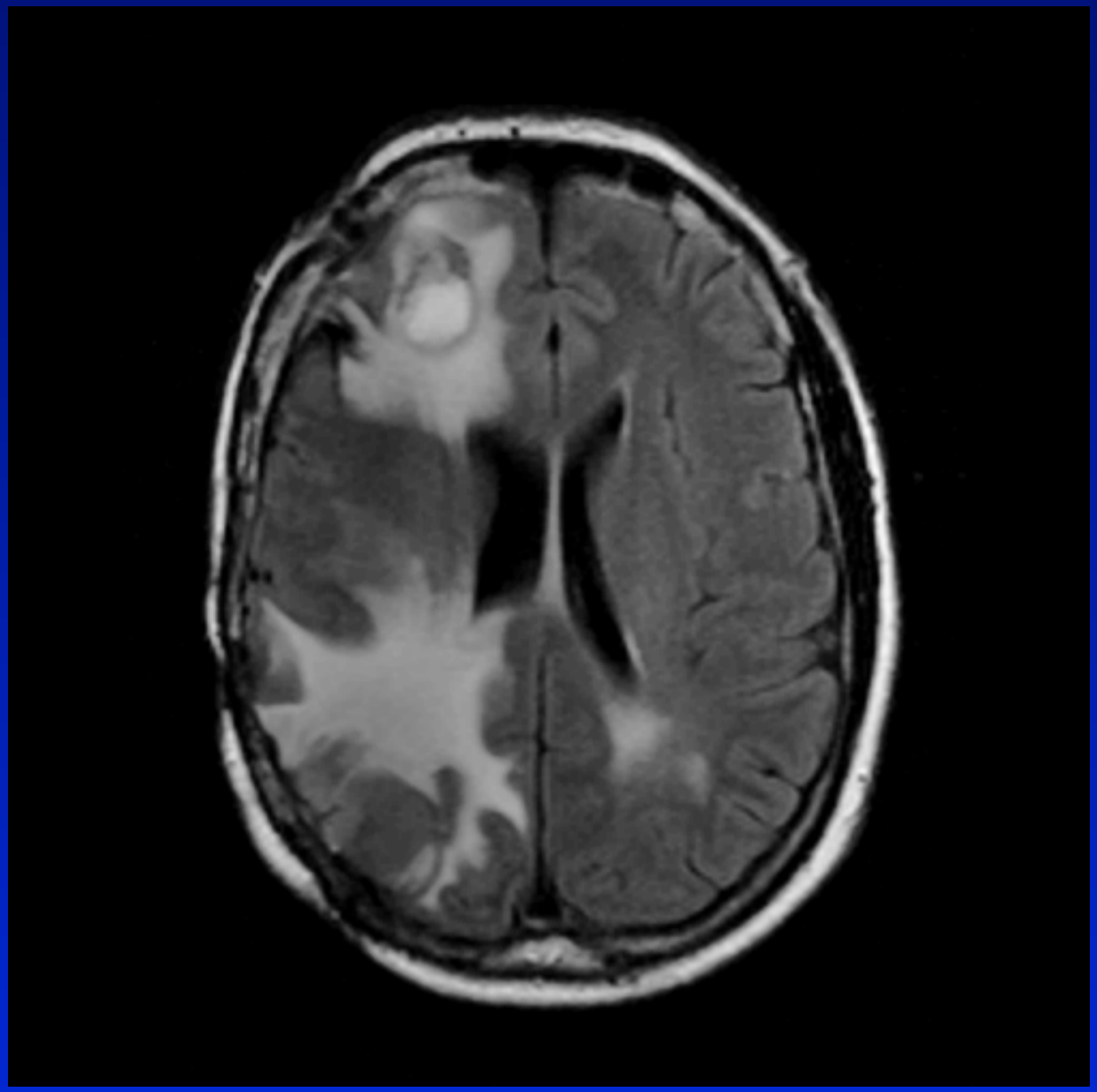


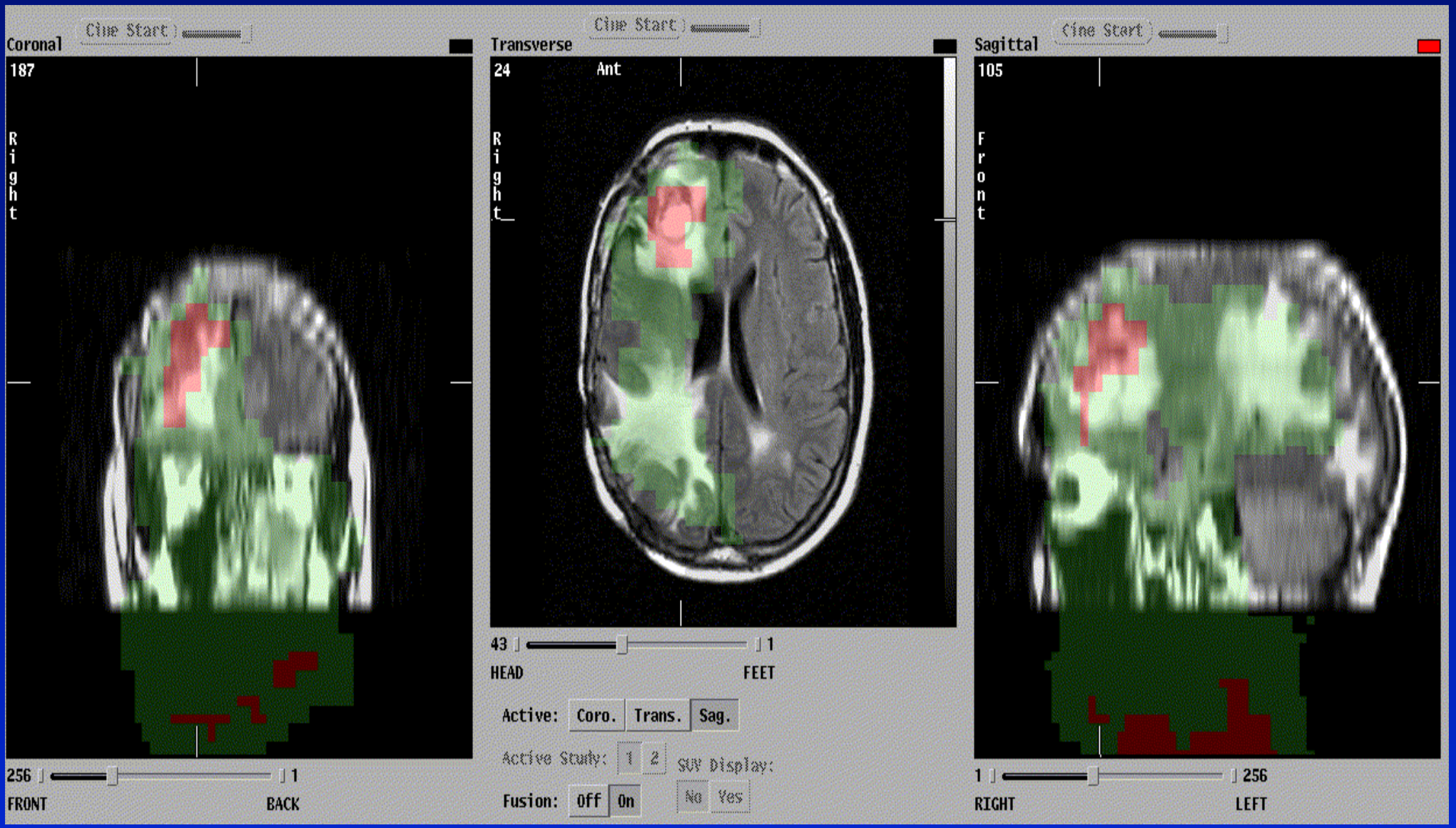
^{99m}Tc HMPAO images superimposed on MR images



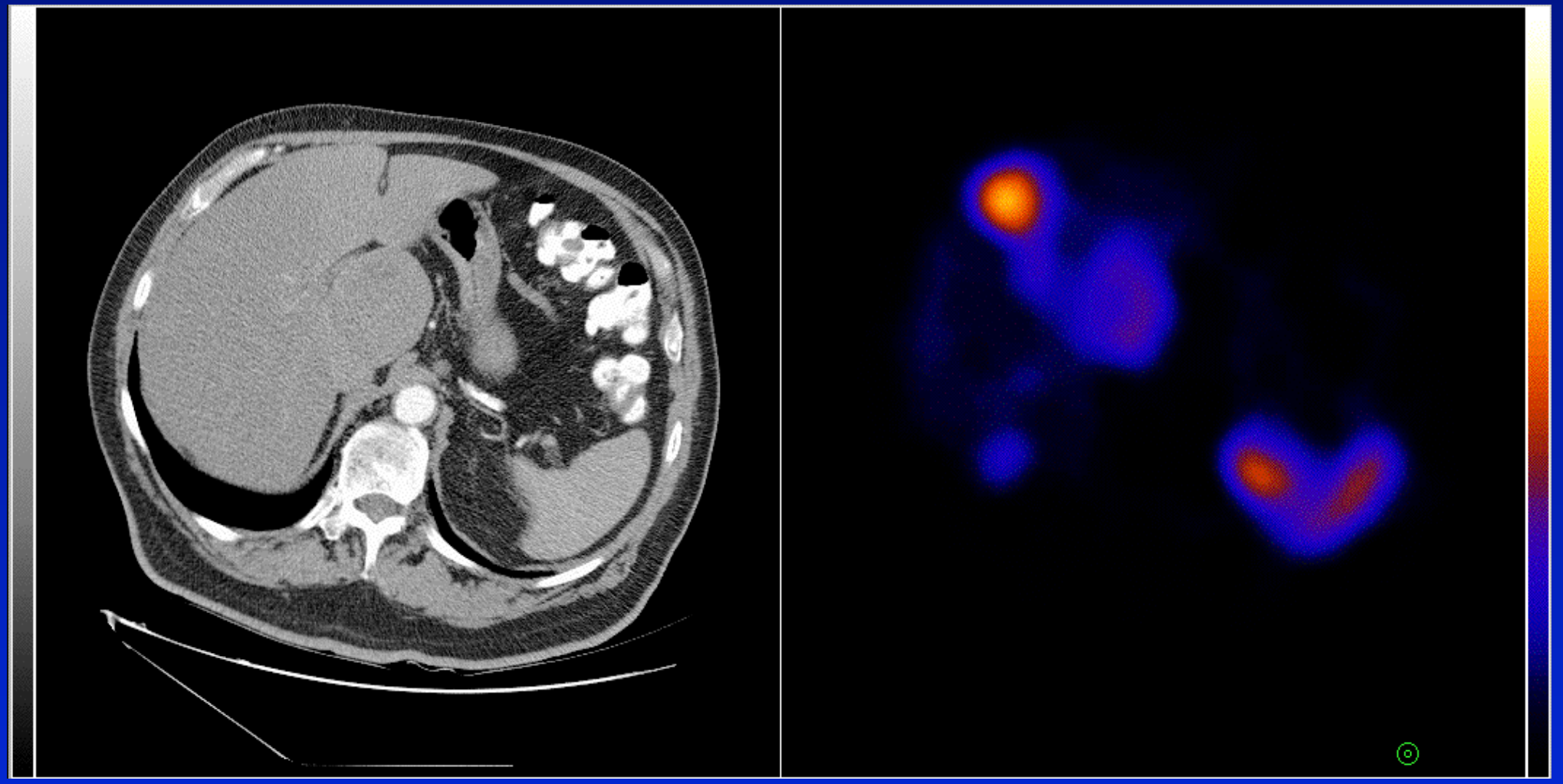
Oncology - Clinical Applications

- Registration MR, CT, SPECT and PET
- Excellent tool in radiotherapy planning
- Biopsy guidance
- Surgical planning
- SPECT (with CEA, prostacint scans, targeted therapy, accurate lesion localisation)

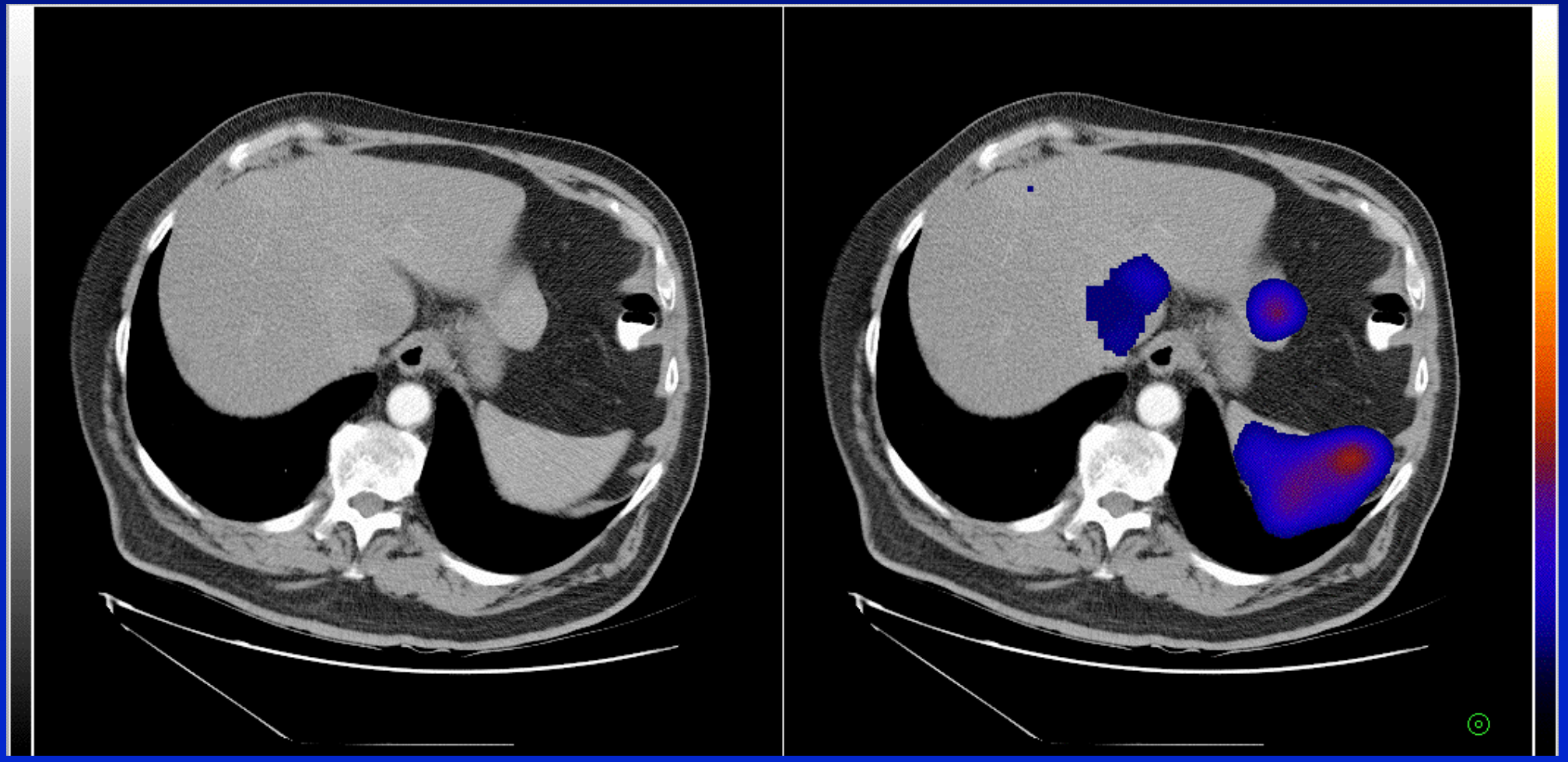



Coronal
Cine Start
187
Right
256
1
FRONT
BACK
Transverse
Cine Start
24
Ant
Right
43
1
HEAD
FEET
Active:
Coro.
Trans.
Sag.
Active Study:
1
2
SUV Display:
Fusion:
Off
On
No
Yes
Sagittal
Cine Start
105
Front
1
256
RIGHT
LEFT

SRS Registered



SRS Fused

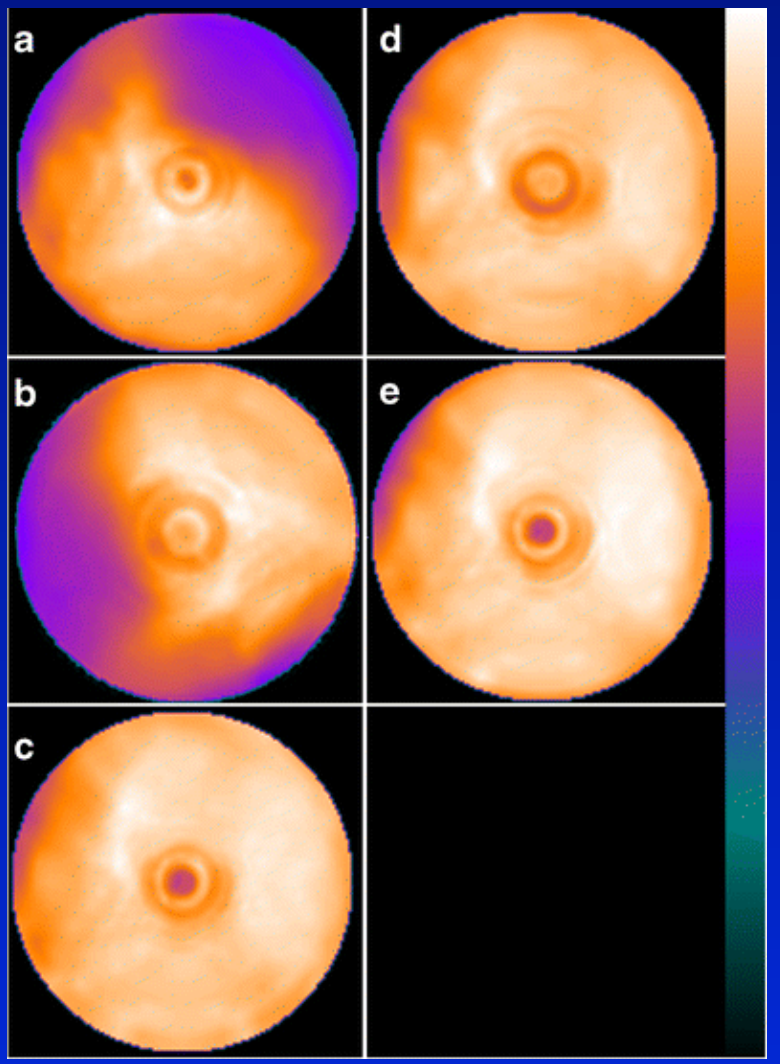


Pitfalls and problems

- *Not unique to SPECT-CT but may be worse because of longer acquisition times*
- *Respiration and mis-registration and AC-errors in lower chest, liver and spleen*
- *Over correction around high density objects in iterative recon-suggest use back-projection*

Effects of movement of chest

- *McQuaid and Hutton UCL, EANMMI*
- *a) cardiac mismatch*
- *b) heart and liver overlap*
- *c) lung movement-diaphragm*
- *d) lung movement chest wall*
- *e) correct image*



Is it being used?

- Despite undoubted advantages, clinical applications limited
- Limitations
  - requires knowledge of registration methods
  - can be misused and is time consuming
  - very mathematical (involve a physicist)
  - easier with automated systems
  - movement (subject, diaphragm, cardiac)
  - organ changes (GB, bladder)

In Summary

- Powerful, versatile and available tool
- Does have limitations and must be used with caution
- Clinical use of dedicated hardware and software registration will increase
- Software registration will remain important for hardware devices