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

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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





Perfect single head poor COR heads

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 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



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)

$$u = p_1 x + p_2 y + p_3 z + p_4$$

$$v = p_5 x + p_6 y + p_7 z + p_8$$

$$w = p_9 x + p_{10} y + p_{11} z + p_{12}$$

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



Landmark Mode

Intrinsic Markers



Landmark Mode

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

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)

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 ACerrors 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