Introduction to PET/CT in Oncology: Practical Aspects

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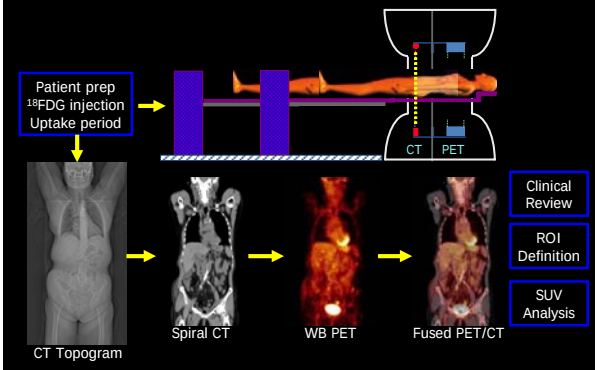
Outline

- Image registration and fusion
- Visualization of PET and CT images
- Acquisition considerations
- Potential artifacts
- Considerations for Quantitative Imaging
- Standardized Uptake Value (SUV)

Whole-body PET/CT protocol



Definitions

- Image registration: Process of matching the spatial coordinates between two or more images
- Image fusion: Process of combining multiple images of a scene to obtain a single composite image

Image registration: the problem

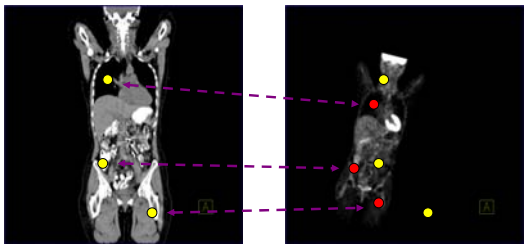


Image registration: zoom

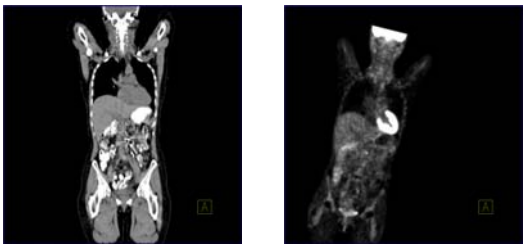


Image registration: rotate

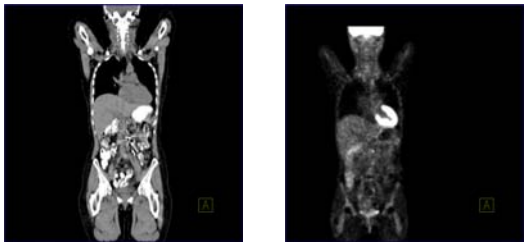


Image registration: translate

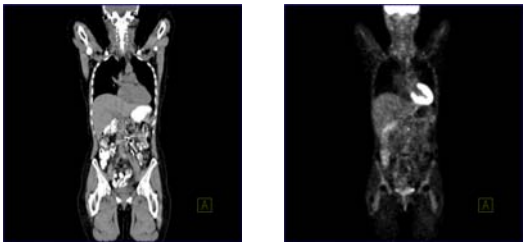
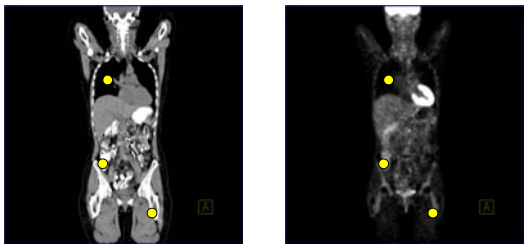


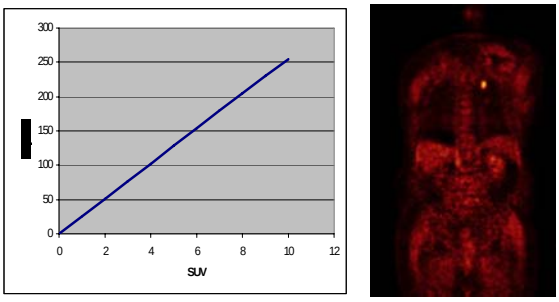
Image registration: complete



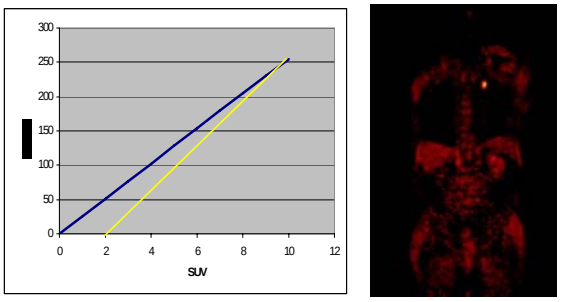
2D display methods

- 2 dimensional reconstructed planes: transaxial, sagittal, coronal, oblique
- Gray scale versus color tables
- Windowing (contrast enhancement)
  - PET: linear scale specified by min & max
  - CT: linear scale specified by center and width

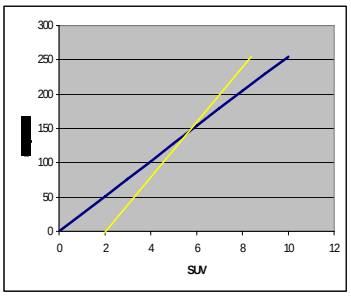
PET windowing: Bottom = 0, Top = 10

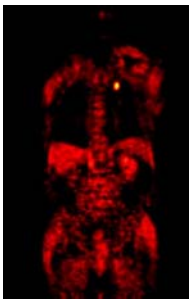


PET windowing: Bottom = 2, Top = 10

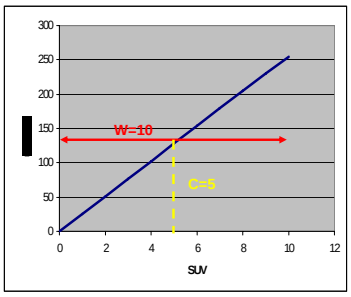


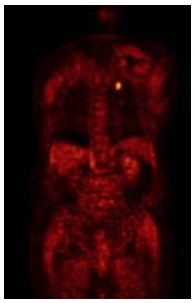
PET windowing: Bottom = 2, Top = 8





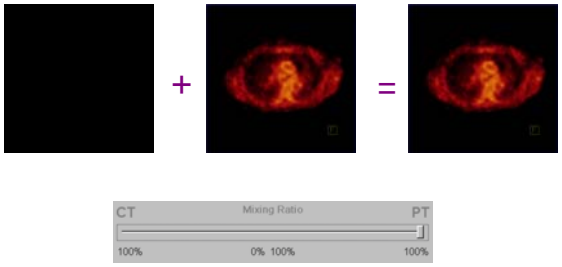
CT windowing notation: Center = 5, Width = 10





CT Windowing

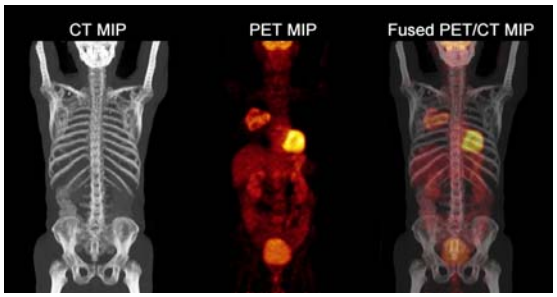
PET/CT Fusion Display



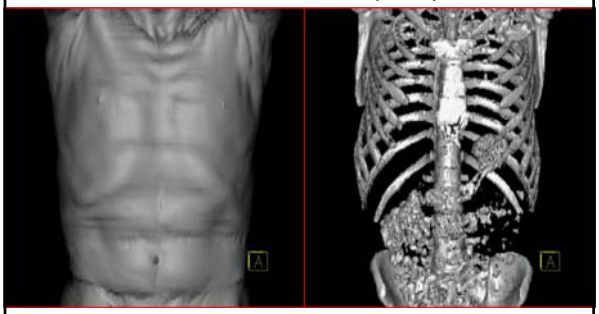
3D display methods

- Maximum intensity projection: Displays the maximum intensity along each projection
- Shaded surface: Displays lighted surface of segmented voxels
- Volume rendering: Displays multiple rendered objects with various transparencies and color tables

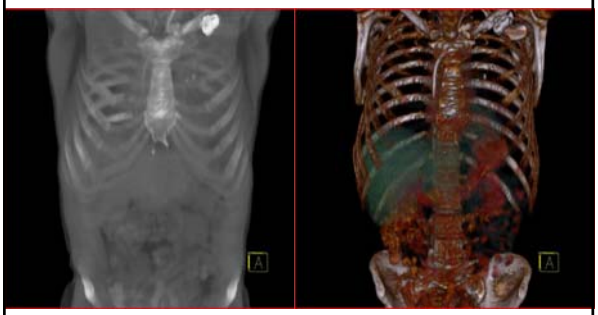
Maximum Intensity Projection (MIP)



3D Display: Shaded Surface (SSD)



3D Display: Volume Rendering Technique



Acquisition Considerations

Options with CT Acquisition

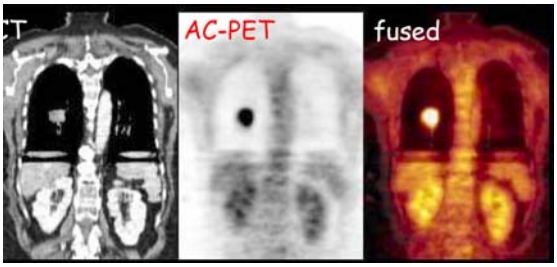
- Breathing protocols
- Arms up for thorax/abdomen
- Arms down for head/neck
- Dose options: attenuation correction only, anatomical localization, full diagnostic
- I.V. and/or oral contrast
- Gated (cardiac or respiratory)
- Dynamic (e.g. perfusion imaging)

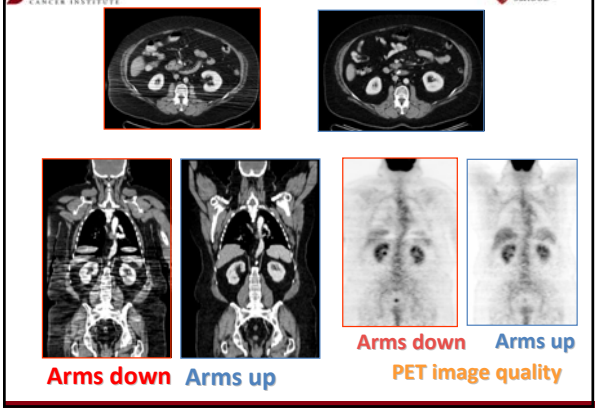
Options with PET acquisition

- Static
- Whole body (multiple bed positions)
  - Step-and-shoot
  - Continuous bed movement
- List-mode
- Dynamic
- Gated (cardiac and/or respiratory)

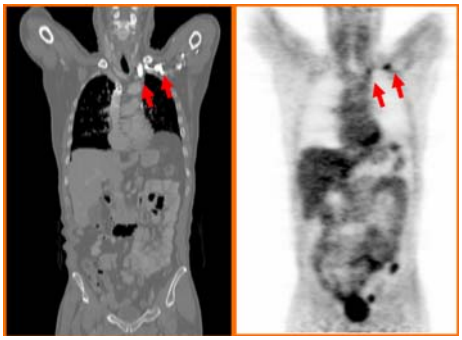
Potential Artifacts

CT-Based attenuation artifacts: respiratory motion

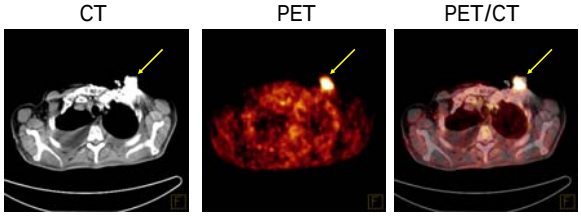




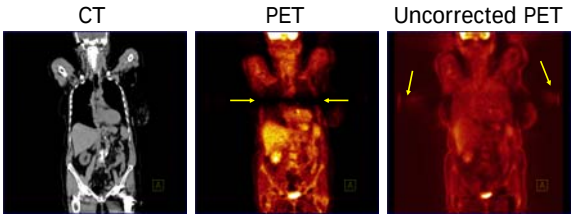
Intravenous contrast media



Chemotherapy port artifact



Movement artifact



Considerations for Quantitative Imaging

- Calibration of all instrumentation is required at commissioning and regular intervals (PET/CT scanners, dose calibrators, scales, clocks)
- Consistent patient preparation is critical (e.g. fasting)
- Technical acquisition should be standardized and critical parameters should be recorded

Hardware/Software Requirements for Accurate SUV Quantification

- Dose calibrator accuracy – traceable standard
- Scanner normalization (detector efficiency)
- Scanner calibration
- PET corrections: attenuation, scatter, randoms, decay (images and doses)
- Partial volume correction for small objects
- Appropriate reconstruction algorithm
- Daily/weekly/monthly scanner QC

Requirements for Reproducible SUV Quantification

- PET technique: ^{18}FDG dose, ^{18}FDG uptake period, emission scan length, scanning range, scanning direction (e.g. head to toe)
- Patient preparation: fasting, resting, medication
- Reconstruction parameters: slice thickness, filters
- Region-of-interest definition methods (mostly manual or semi-automated)
- Consistency is the most important factor!

Mandatory measurements

- Acquisition parameters
- Patient height, weight
- Injected activity, residual, and time
- Circulating glucose
- Infiltrated doses
- Patient compliance (e.g. fasting state, movement)
- Protocol deviations
  - Injection time/scan delays
  - Injected activity

Standardized Uptake Value

SUV (time) = Radioactive Concentration x Weight
Injected Activity

- Under certain circumstances, ^{18}FDG SUV correlates with metabolic rate of glucose and/or the number of viable tumor cells
- Simplified semi-quantitative measure that can be routinely performed in clinical PET studies
- Adjusts for differences in patient size and injected activity

SUV Units

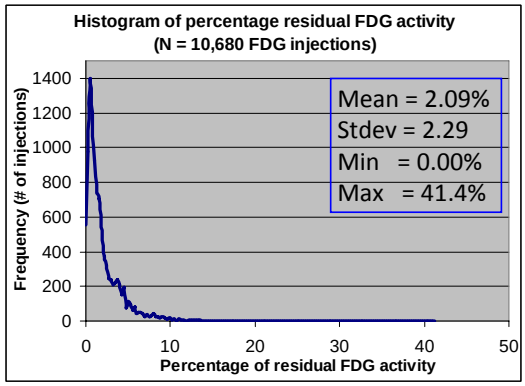
- Assuming the following:
  - water-equivalent tissue
  - a body weight correction in grams
  - decay-correction to the time of injection
  - Concentration in consistent units of mCi/ml or MBq/cc
- The SUV is a unit-less quantity
- The SUV has a value of 1 if the radiotracer is uniformly distributed

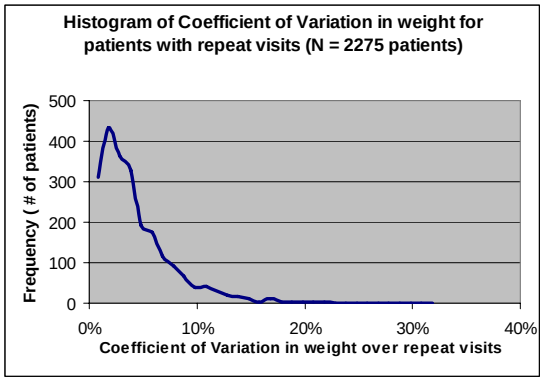
SUV Example

- Consider 0.8 ml volume containing 12 mCi of ^{18}FDG is "injected" into a 1.5 liter volume of water
- **SUV = Radioactive Conc. x Weight**
  Injected Activity
- **SUV = (12 mCi / 1500 ml) * 1500 g (1 ml/g)**
  12 mCi

Variations in SUV

- Use of body surface area or lean body mass instead of weight
- Sometimes denoted with subscripts (SUV_{BW}, SUV_{BSA}, SUV_{LBM})
- Linear correction for circulating glucose
- Designated uptake period – delayed scanning may reduce background physiologic uptake
- Various statistics: mean, max, peak





The Good News

- Most differences in scanner hardware and reconstruction software cancel out in longitudinal studies of the same patient
- Although there is no universal cutoff, the SUV can help differentiate malignancy from normal tissue
- Changes in SUV after therapy have been shown to correlate with clinical outcome (e.g. survival)