Quantitative Methods and Factors Affecting SUV Calculation

Steven Meikle, Ph.D.

Principal Hospital Scientist
Dept of PET & Nuclear Medicine
Royal Prince Alfred Hospital, Sydney

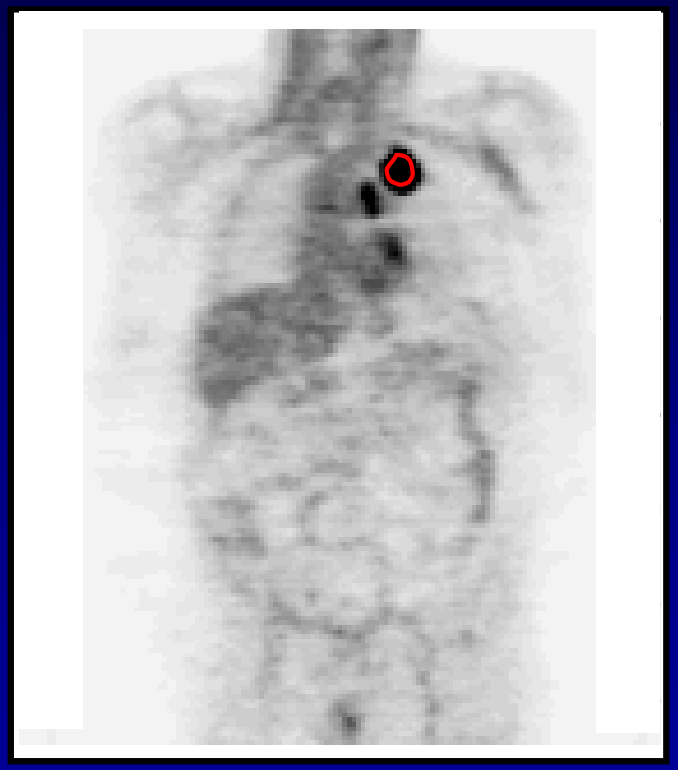
Standardised Uptake Value (SUV)

$$SUV = \frac{C(T)}{\text{dose/body weight}}$$

where $C(T)$ = FDG concentration in tissue at time T

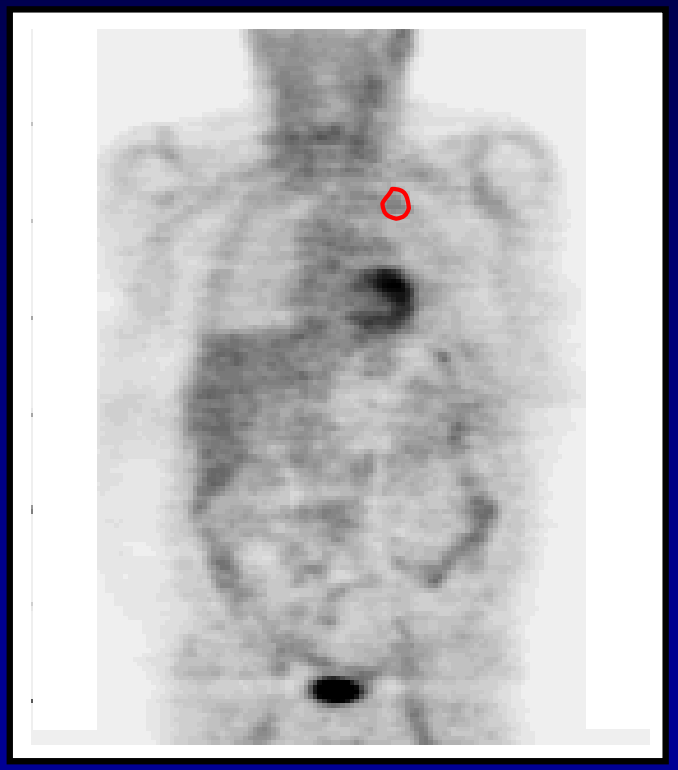
Standardised Uptake Value (SUV)

Before Tx



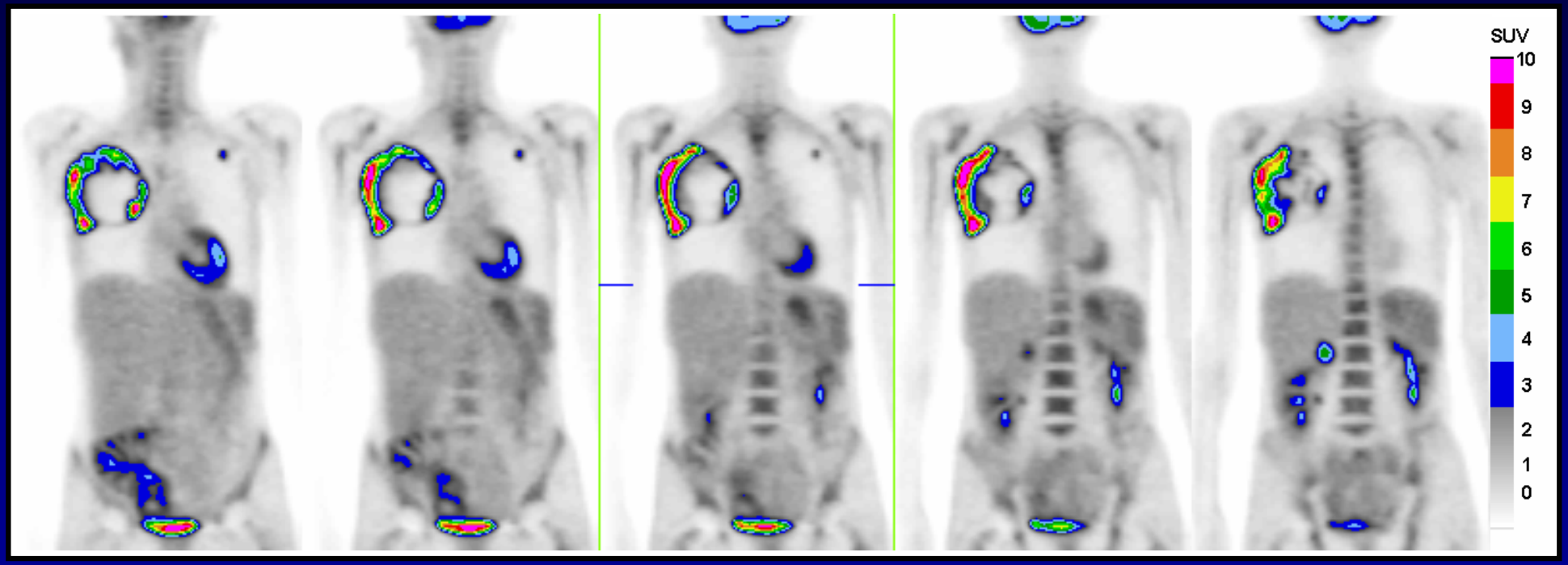
SUV = 18

After Tx



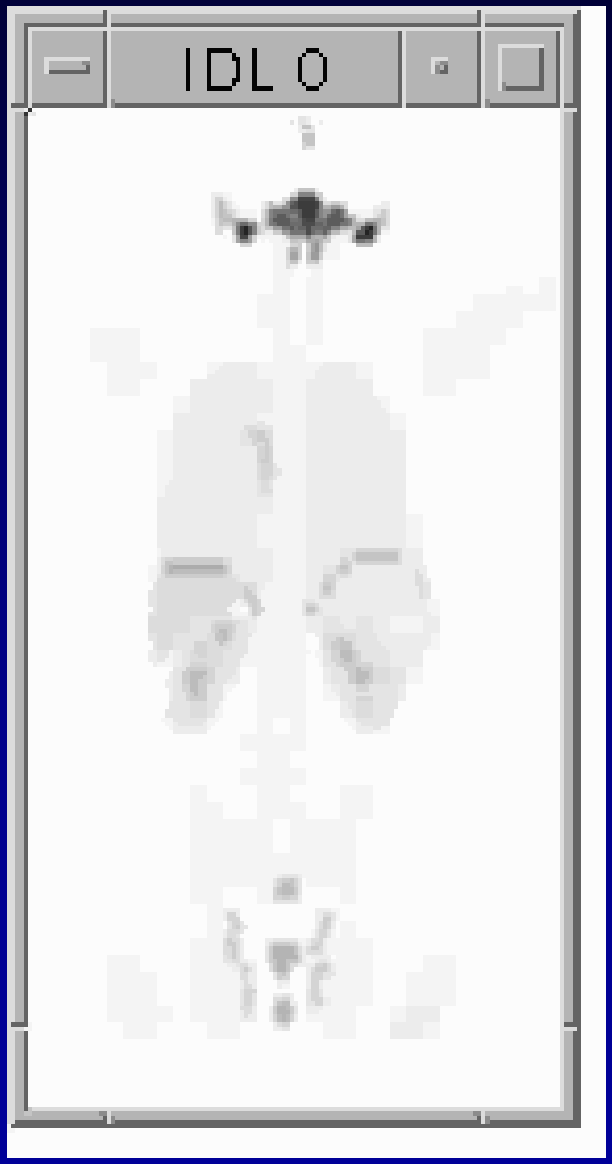
SUV = 4

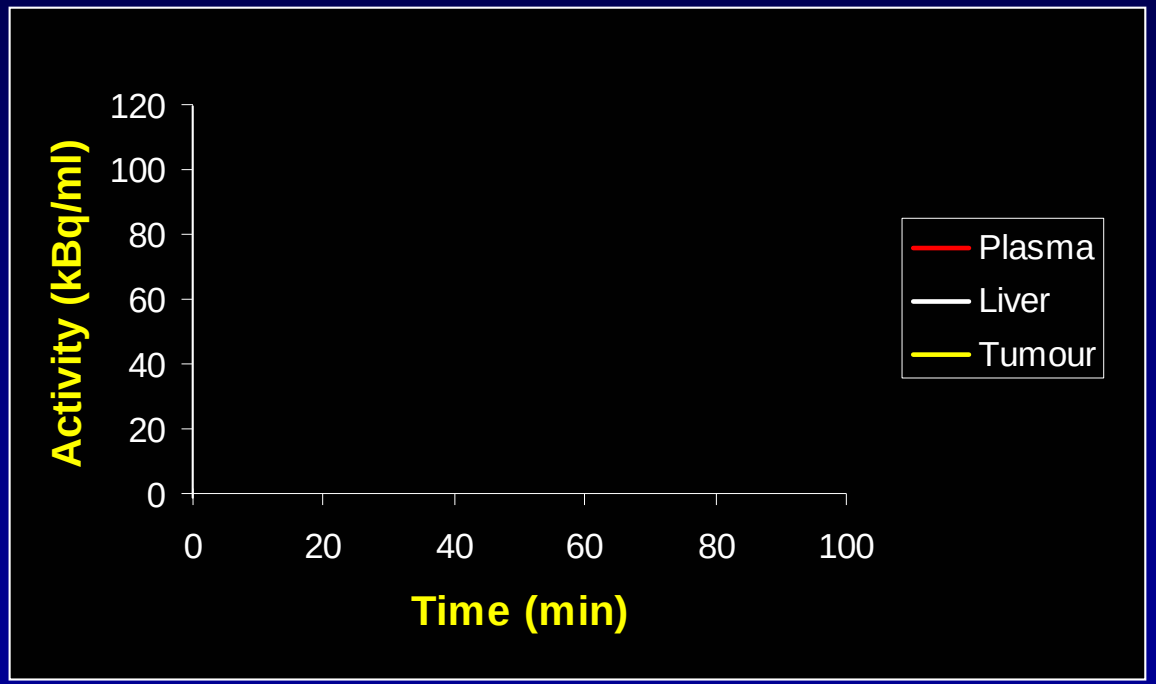
Standardised Uptake Value (SUV)



Data Courtesy of Mount Vernon Hospital

FDG Uptake as a Function of Time





Factors Affecting FDG Uptake Determination

- Administered dose
- Size of patient (weight & fat content)
- Blood perfusion of the tissue
- **Concentration of glucose transporter**
- **Rate of phosphorylation**
- Competition with endogenous glucose
- Time of uptake determination after tracer administration
- Accuracy of attenuation, scatter, randoms & deadtime correction
- Size & concentration of tumour relative to bkg and spatial resolution of scanner
- Size and placement of region of interest (ROI)

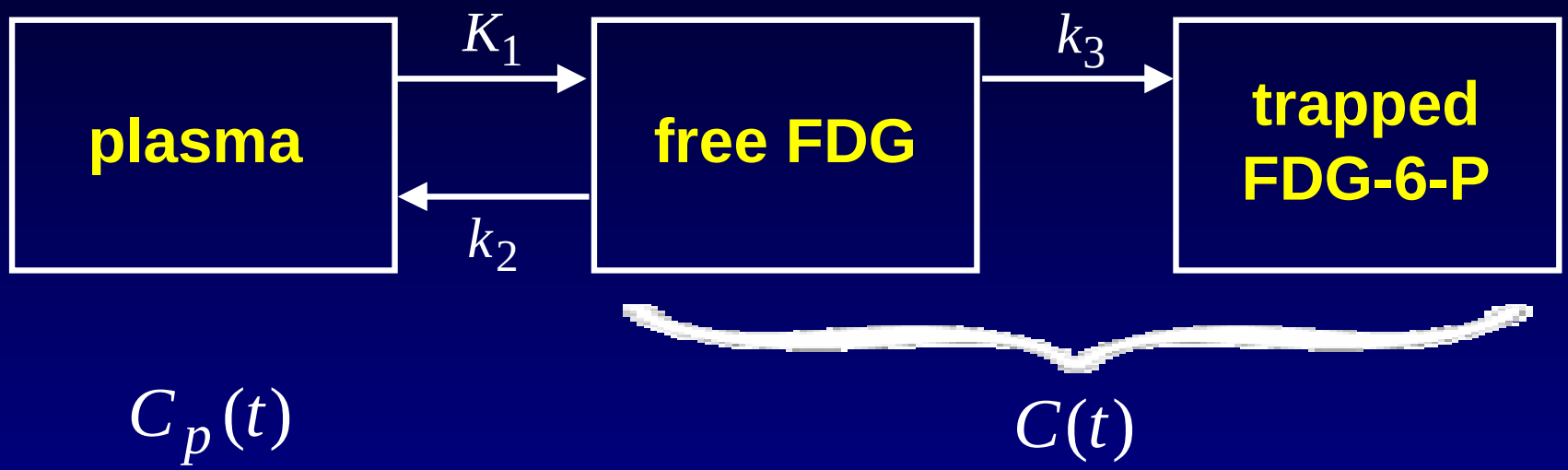
FDG Model

$$MRGlc = \frac{Glc}{LC}\left(\frac{C(T) - K_1\int_0^T C_p(t)e^{-(k_2+k_3)(T-t)}dt}{\int_0^T C_p(t)dt - \int_0^T C_p(t)e^{-(k_2+k_3)(T-t)}dt}\right)$$

FDG Model

$$MRGlc = \frac{Glc}{LC}\left(\frac{\mathrm{C}(T) - \text{free FDG in tissue at time T}}{\int_0^T (\text{FDG in plasma} - \text{lag term})\, dt}\right)$$

FDG Model



$$MRGlc \approx \frac{Glc}{LC}\left(\frac{C(T)}{\int_0^T \text{FDG in plasma } dt}\right)$$

FDG Model

$$MRGlc \approx \frac{Glc}{LC}\left(\frac{C(T)}{\text{b} \cdot \text{dose}/\text{body weight}}\right)$$

FDG Model

$$MRGlc \approx \frac{Glc}{LC \cdot b}\left(\frac{C(T)}{\text{dose}/\text{body weight}}\right) = \frac{Glc}{LC \cdot b}(\text{SUV})$$

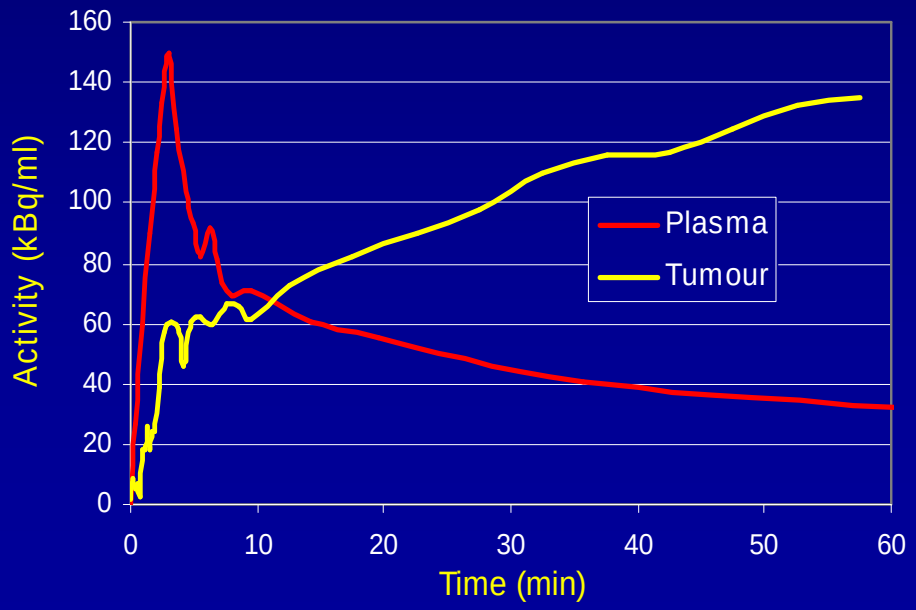
Assumptions of SUV Method

- Negligible free FDG in tissue at time of PET scan
- Equilibrium reached between plasma and free FDG in tissue
- Integrated plasma FDG curve is proportional to dose and inversely proportional to body weight
- All tissues are similarly affected by changes in endogenous glucose levels

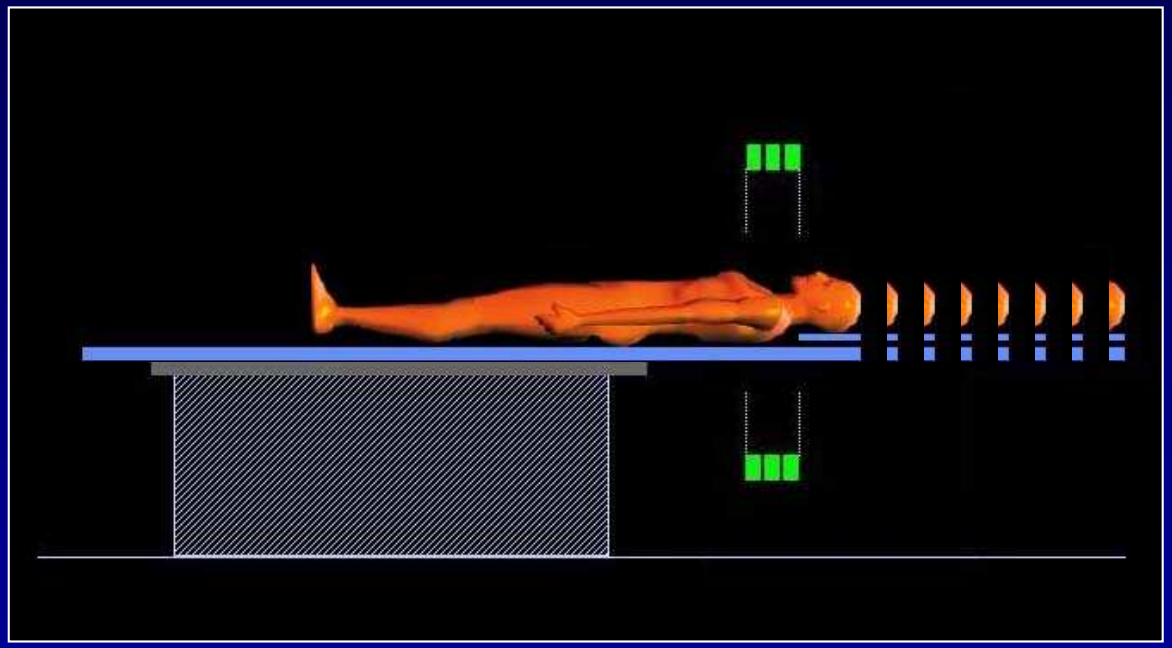
Assumptions of SUV Method

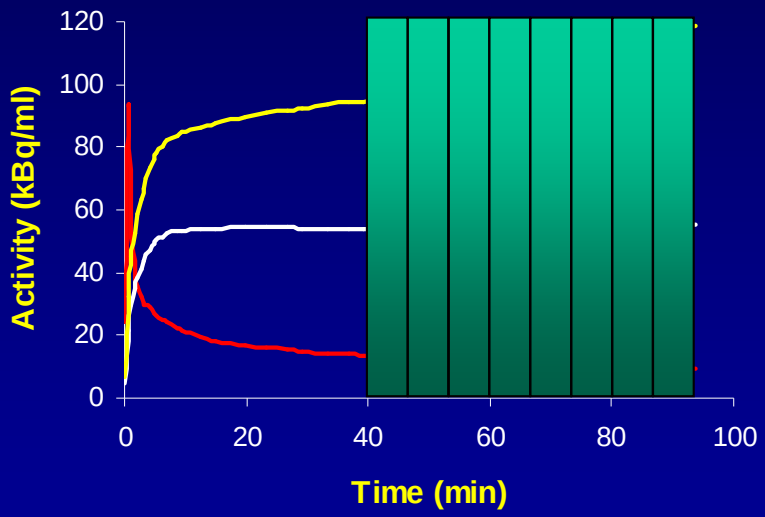
- Negligible free FDG in tissue at time of PET scan
- Equilibrium reached between plasma and free FDG in tissue

Reasonable provided T > 40 minutes in most tissues and tumours, except lung Ca



Scan Time is Different for Different Tissues





Assumptions of SUV Method

- Integrated plasma FDG curve is proportional to dose and inversely proportional to body weight

Reasonable except when kidney function disturbed, eg as a result of ChemoRx, and when body fat is high. Some advocate use of lean body mass rather than body weight.

Assumptions of SUV Method

- All tissues are similarly affected by changes in endogenous glucose levels

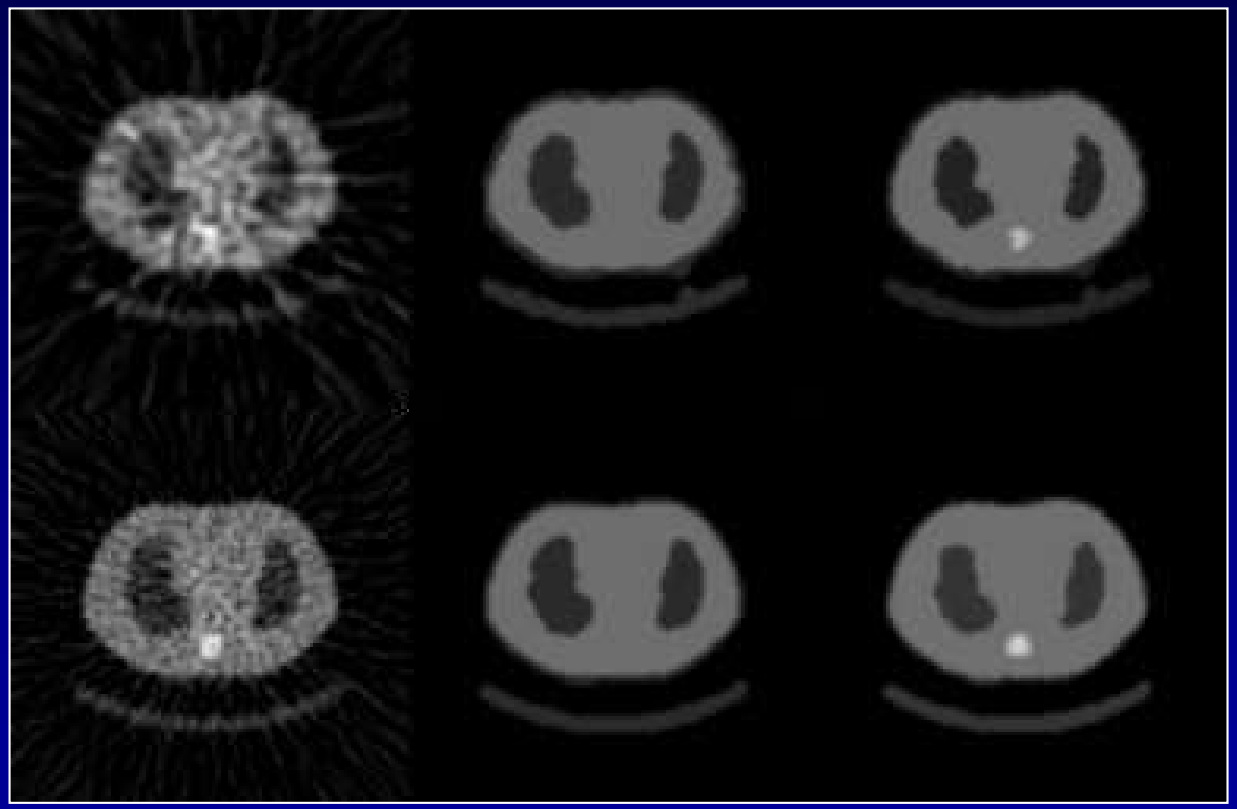
Uptake in most tumours, brain, small bowel and ovaries is inversely proportional to plasma glucose level while MRGlc remains approx constant. Opposite relationship holds for kidney and skeletal muscle and some tumours during hypoglycaemia.

Effect of Attenuation Correction

- Measured AC is accurate but increases uncertainty due to noise
- Segmented AC reduces uncertainty due to noise but increases bias

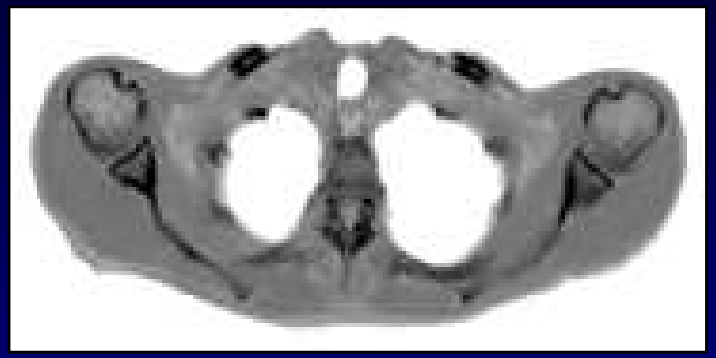
3 min acqu

16 min acqu

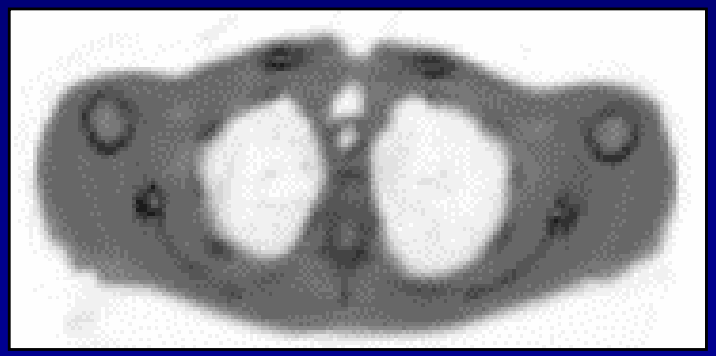


measured **histogram-based segmentation** **adaptive segmentation**

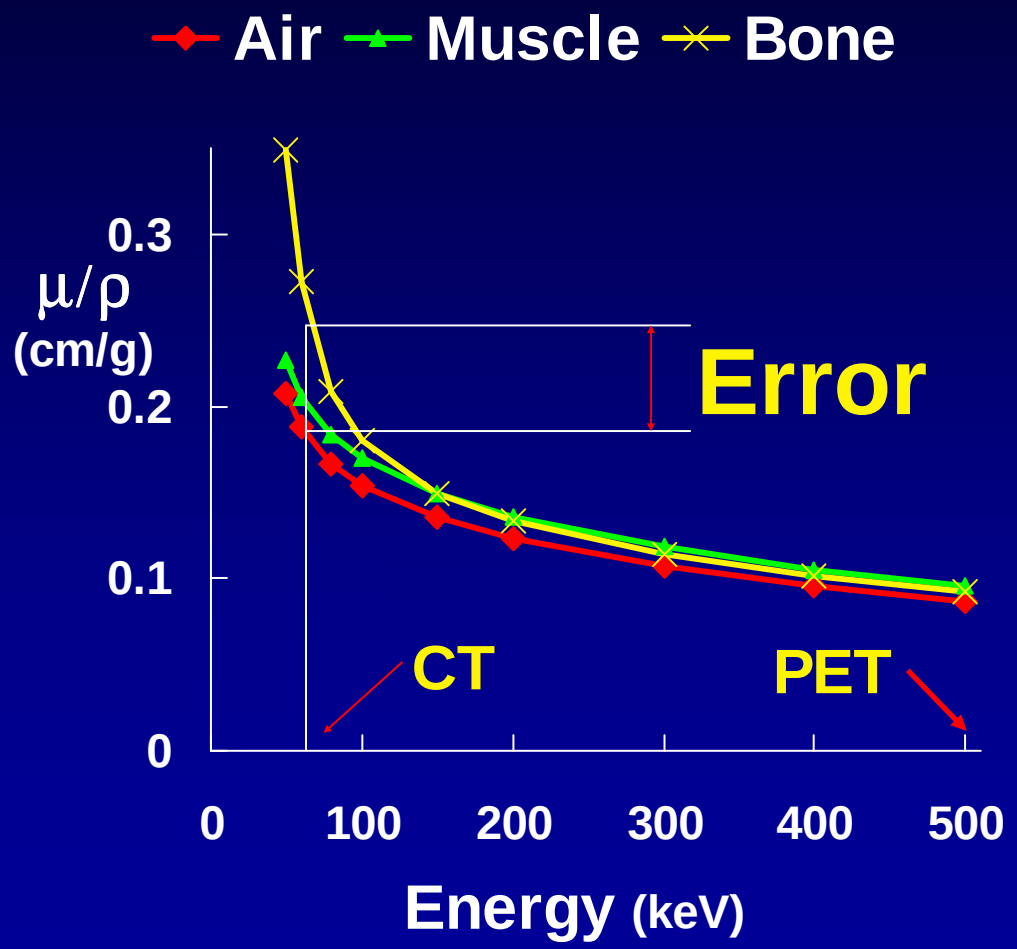
CT-based Attenuation Correction



CT: 70 keV

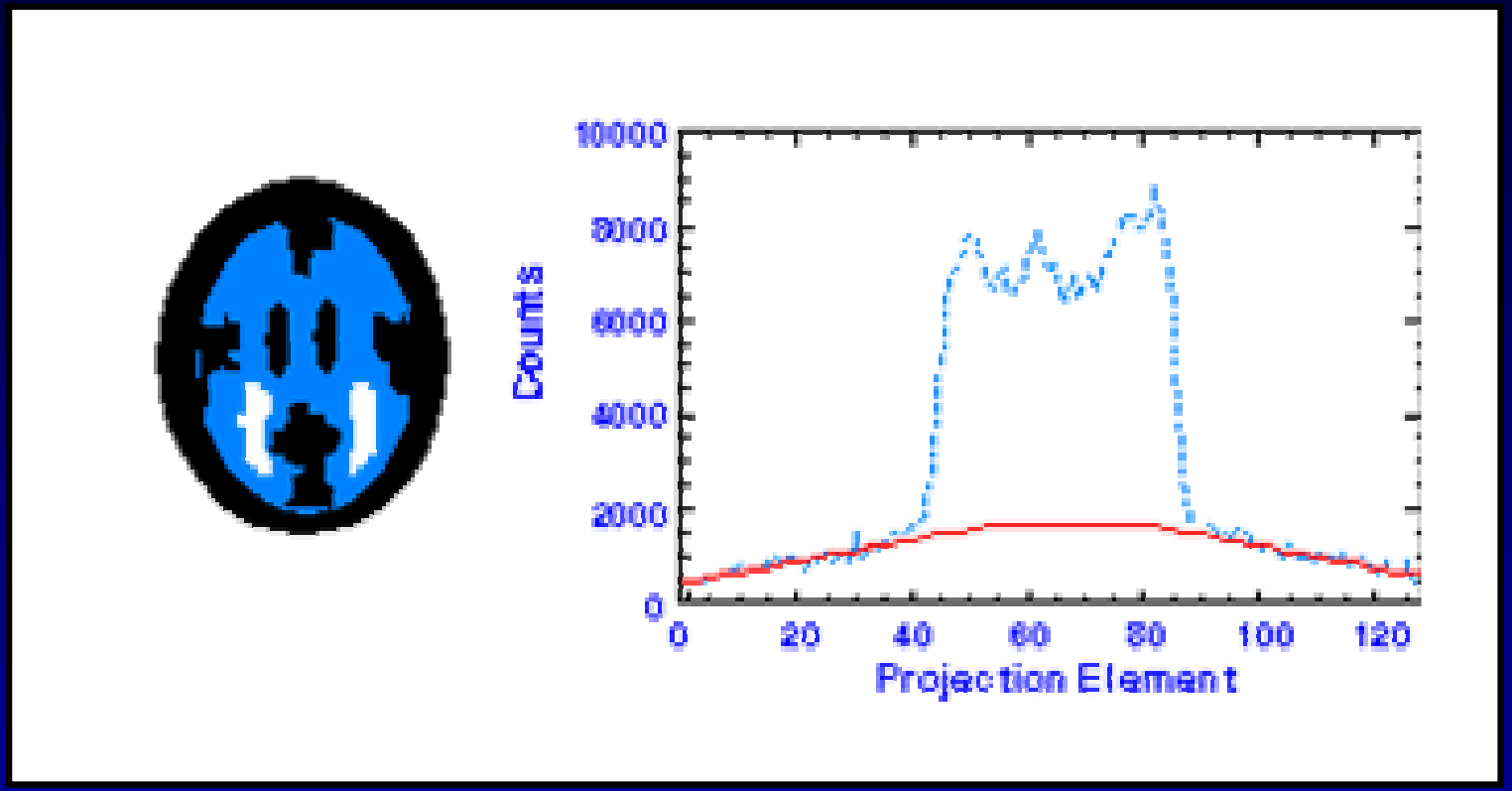


Scaled: 511 keV



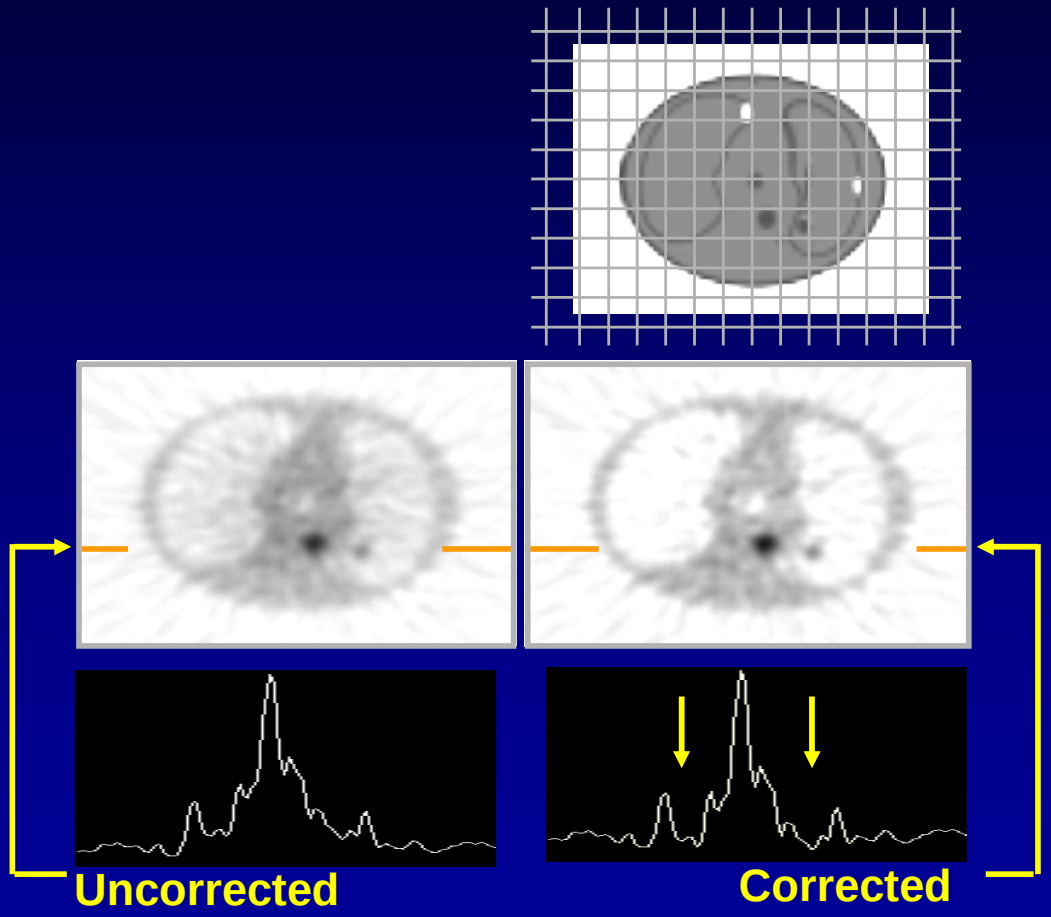
Courtesy of David Townsend, University of Pittsburgh Medical Center

Scatter Correction: Tail Fitting Method



- Prone to error especially in the body where scatter tails are narrow. May not work at all in large patients.

Simulation-based Scatter Correction

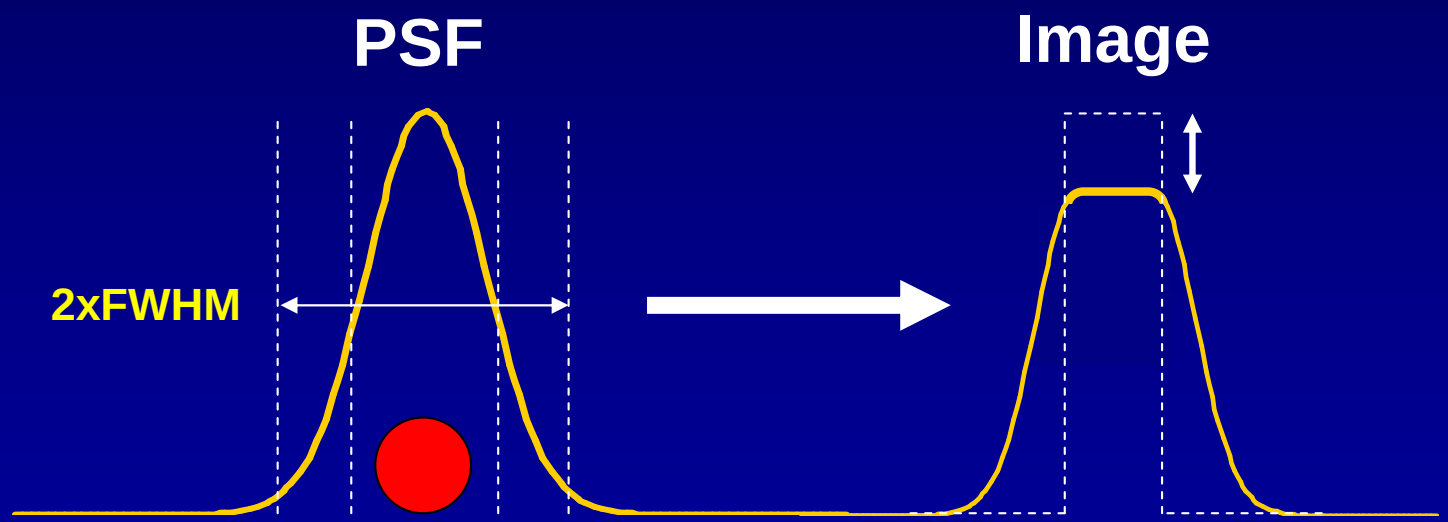


- More accurate and takes account of patient specific geometry but doesn't account for scatter from activity outside FoV

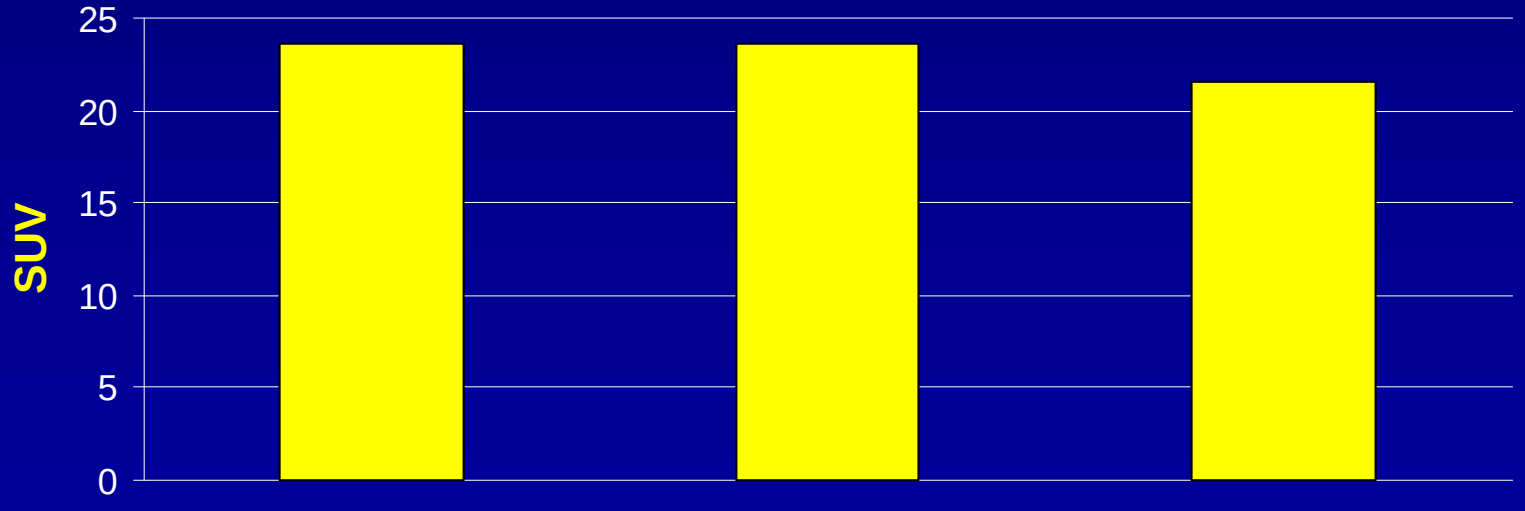
Courtesy of Charles Watson, CTI PET Systems

Partial Volume Effect

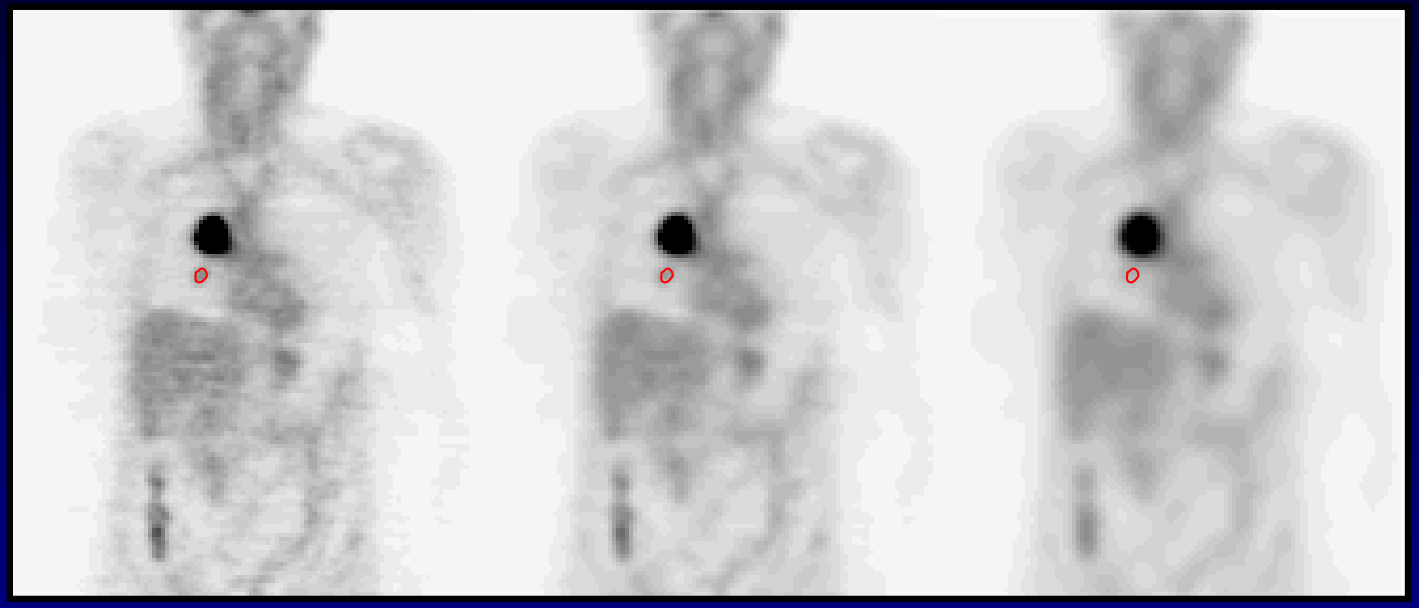
When an object partially occupies the sensitive volume of an imaging instrument (in space or time) the measured signal will be reduced in amplitude (diluted).



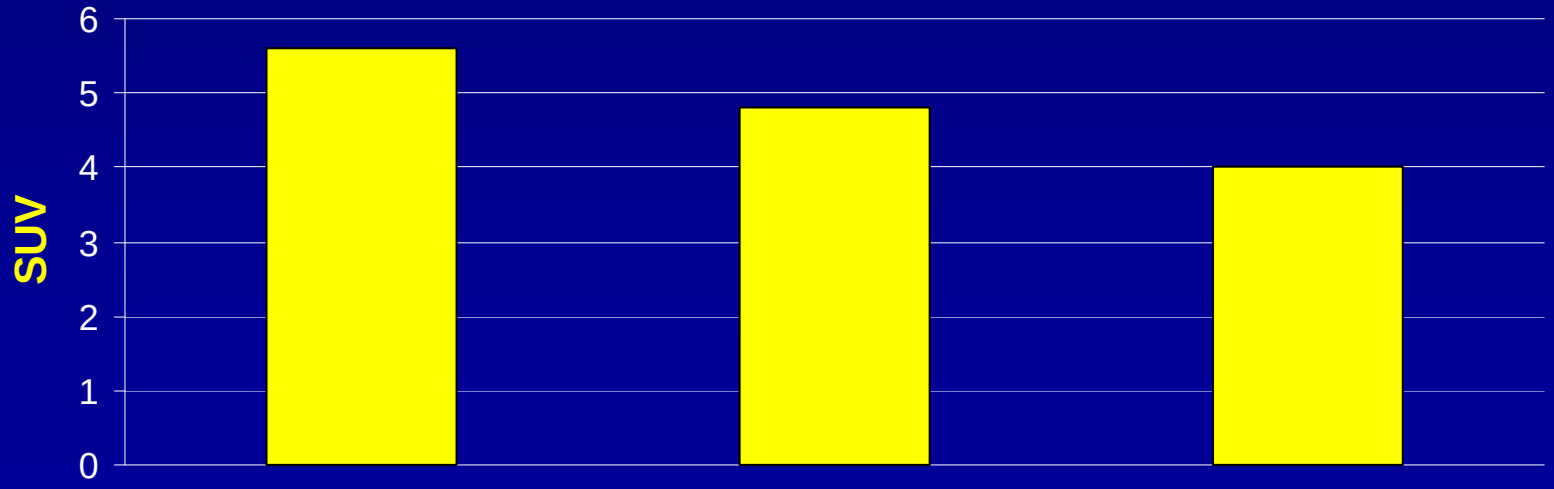
Effect of Resolution & Tumour Size on SUV



Effect of Resolution & Tumour Size on SUV



10 mm 15 mm 20 mm



Assumptions of SUV Method

Assumption	Magnitude of error
Negligible free FDG in tissue at time of PET scan	< 10% (except lung Ca)
Equilibrium reached between plasma and free FDG in tissue	< 10%
Integrated plasma FDG curve is proportional to dose and inversely proportional to body weight	> 30%
All tissues are similarly affected by changes in endogenous glucose levels	?
Attenuation, scatter, etc	≈10%
Resolution, tumour size / concentration	20-30% if ≤ 1cm

Summary & Recommendations

- Standardise imaging protocol, particularly
  - uptake time
  - method of attenuation & scatter correction
  - filtering
  - timing of blood samples for plasma glucose levels
- Take care with ROI placement and use ROI max rather than mean
- Take into account tumour type, glucose levels & possible Tx effects when interpreting SUV
- Use SUV within institution rather than comparing with other institutions or literature values
- Don’t use SUV threshold to distinguish tumour from normal tissue

Bottom Line

Recognise the SUV for what it is,
a simplified index of FDG uptake

and…

Use it with caution!

References:

JW Keyes, “SUV: Standard Uptake or Silly Useless Value?”, *J Nucl Med* 36:1836-1839, 1995

S-C Huang, “Anatomy of SUV”, *Nucl Med Biol* 27:643-646, 2000