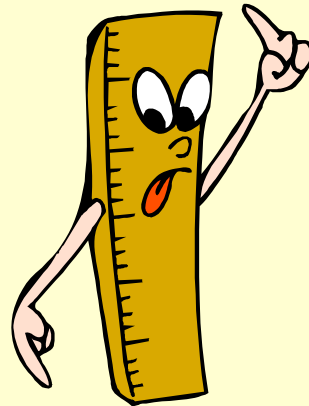


Quantification in oncologic FDG-PET: A scientific overview



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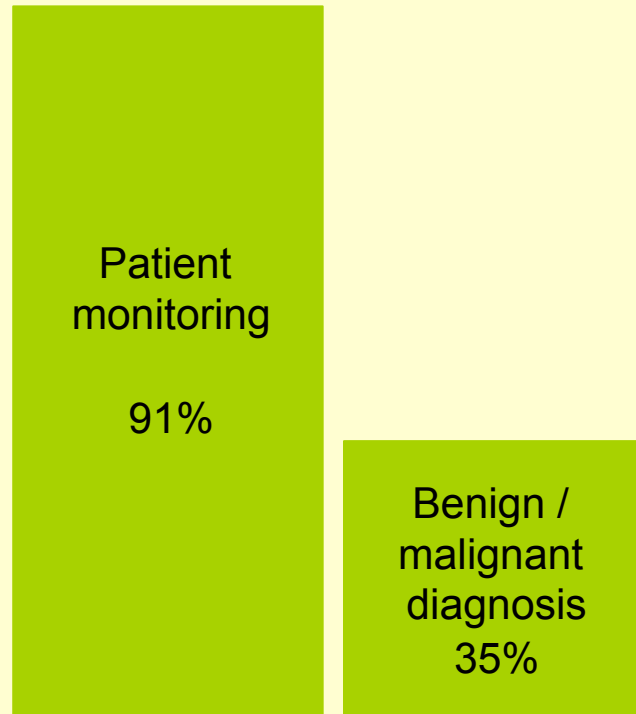
<http://www.guillemet.org/irene>

Quantification is becoming a real need

90% of sites includes SUV in the PET/CT report

Beyer et al, J Nucl Med 2011

Why considering SUV ?



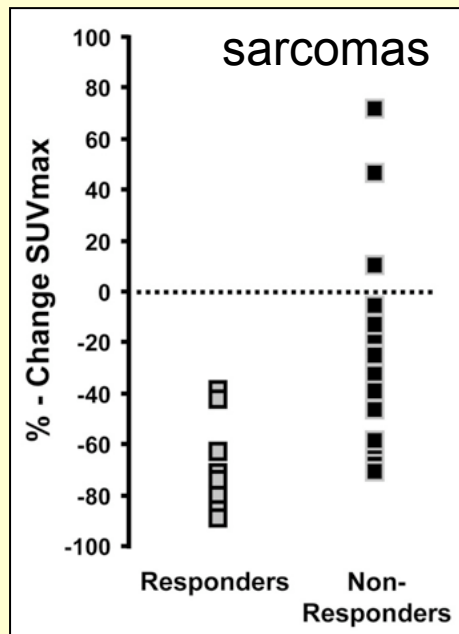
+ to delineate of metabolically active volume for treatment planning in radiotherapy

Beyer et al, J Nucl Med 2011

Does that work?

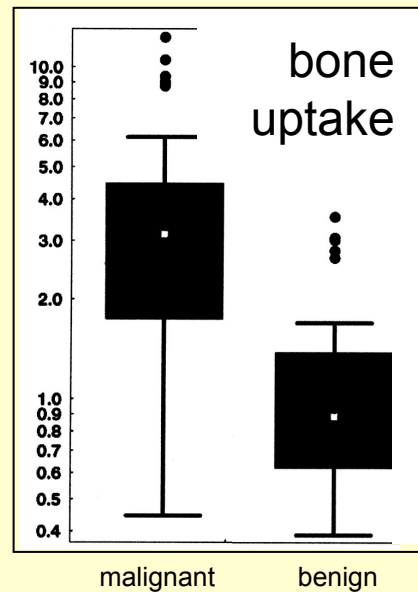
There is large evidence in the literature that :

- SUV changes can effectively separate histopathologically responding and non responding tumours



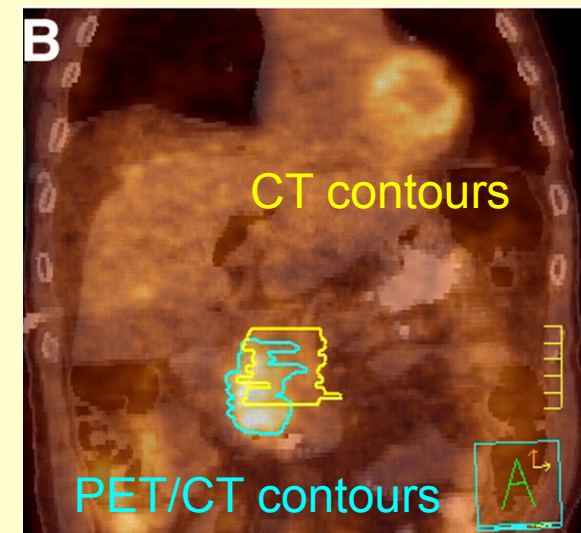
Benz et al, J Nucl Med 2008

- SUV helps distinguish between benign and malignant lesions, or between good and poor prognosis



Dimitrakopoulou-Strauss et al, J Nucl Med 2002

- Tumor delineation on PET/CT significantly impacts target definition in radiation treatment planning



Ford et al, J Nucl Med 2009

Why is SUV so useful ?

$$\text{SUV} = \frac{\text{uptake (kBq/mL)}}{\text{injected dose (kBq) / "patient weight (g)" @ scan time}}$$

- If: 1/ the tracer distributes uniformly throughout the patient
2/ patient density is 1 (1g = 1 mL)

SUV = 1 everywhere



SUV > 1, high uptake



Converting images into SUV makes them more **easily comparable across patients: the expected value is 1 for any patient**, whatever the injected activity and the body habitus

Contradictory statements ?

FDG PET/CT and SUV measurements have been proven to be a remarkable effective clinical tool.

The overall cumulative effect of individual factors on quantitative outcome can be large (50-100%)

Boellaard J Nucl Med 2009

Differences in SUV estimates greater than 100% can be caused only by differences in the way data are acquired and processed, which suggest that comparison of SUV between PET centers using different scanning and processing protocols is almost impossible.

Feuardent et al, IEEE Trans Nucl Sci 2005

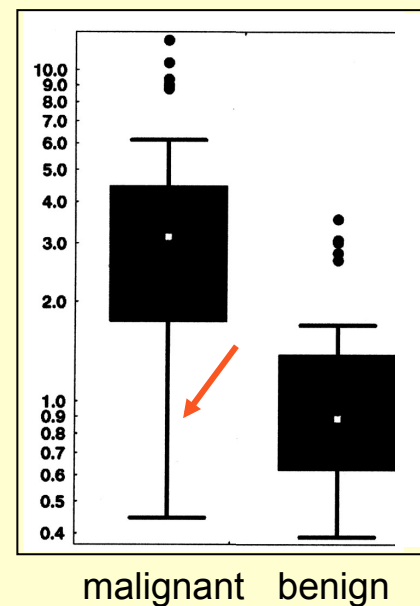
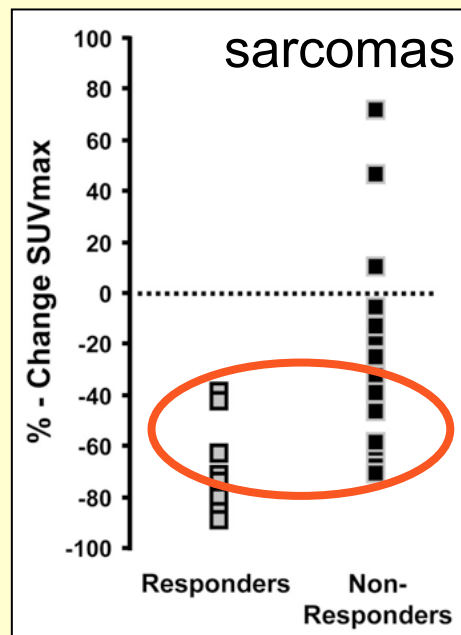
The SUV depended strongly on all studied parameters, and it can only be used for diagnostic purposes when data acquisition and processing are performed in a standardized way. This might be a problem for multicenter studies.

Boellaard et al, J Nucl Med 2004

Answer: No

FDG PET/CT is **robust**
with regard to the acquisition and processing protocols

Yet, for the scientist, this leaves
**considerable room for further enhancing
the clinical utility and diagnostic effectiveness of FDG PET**



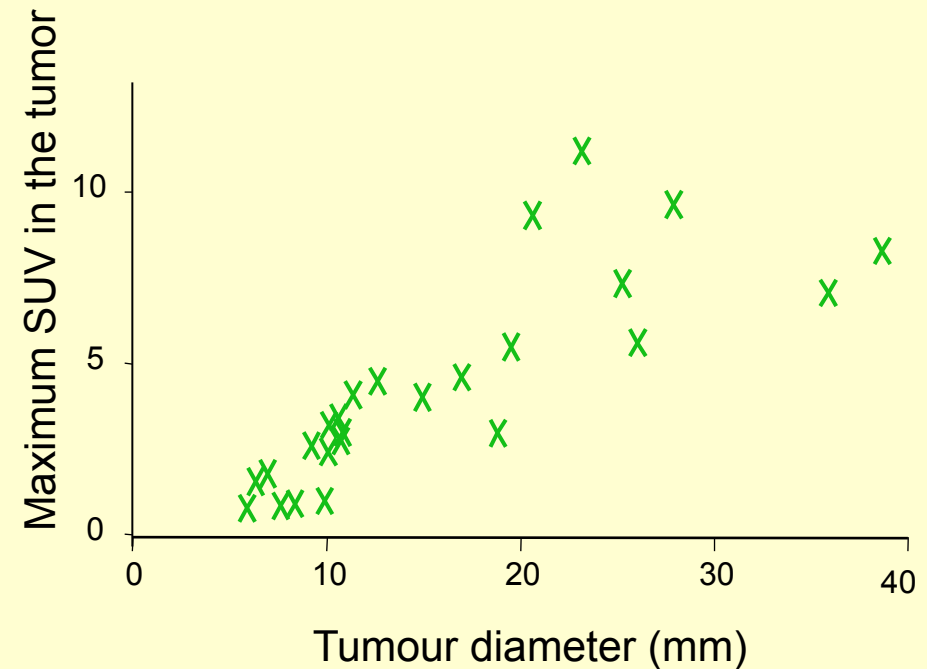
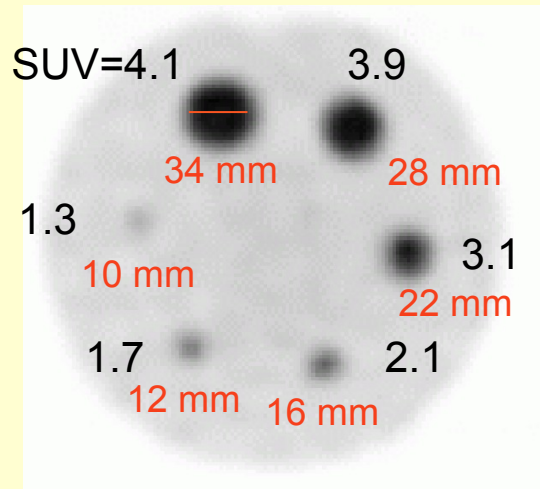
What can we do even better ?



1. Errors in SUV estimates could be significantly reduced
2. Variability in SUV estimates could be significantly reduced
3. Tumour uptake could be more comprehensively described

1. Major source of errors in SUV measurements

Partial volume effect



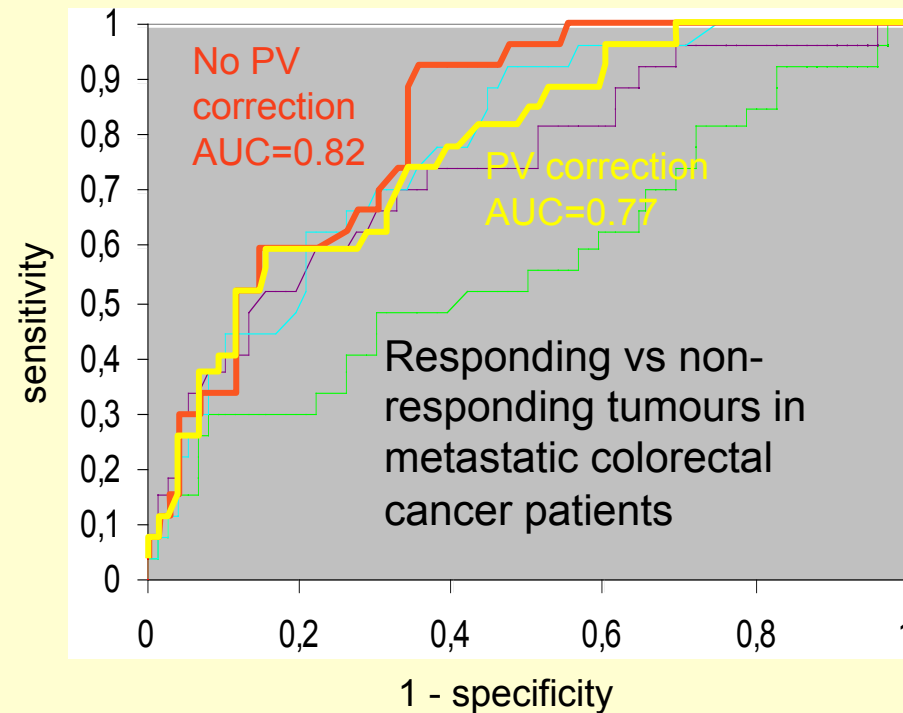
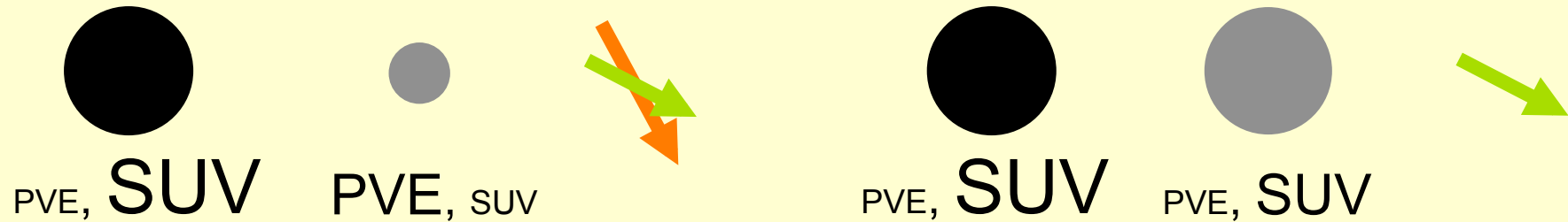
This does not mean that bigger tumours are always more aggressive, but bigger tumours are less affected by partial volume effect !

Ideally: correct for partial volume effect



Good news : PVE can be turned to an advantage !

Patient monitoring



Maisonobe et al, SNM 2011

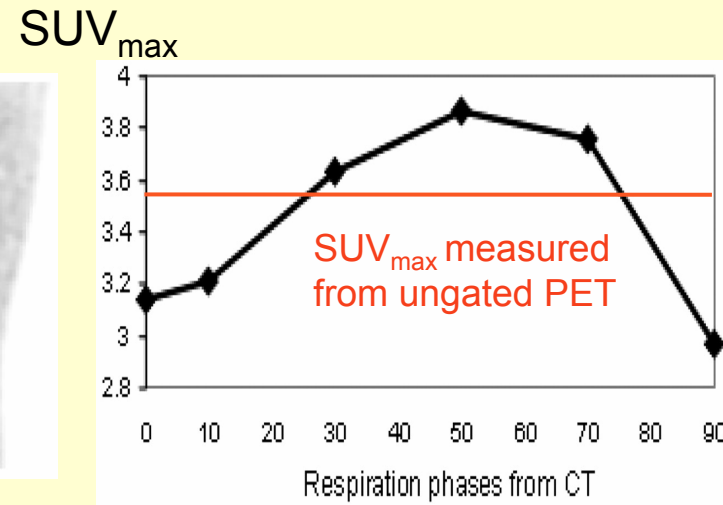
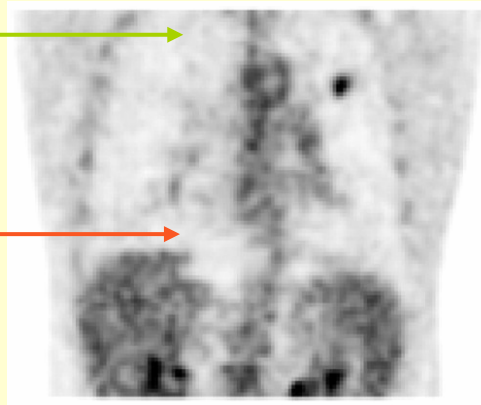
In the context of patient monitoring, PVE can help detect tumour response

Additional sources of bias in SUV measurements (1)

- Respiratory motion

Tumour here: little motion, small SUV underestimation

Tumour here: large motion, large SUV underestimation



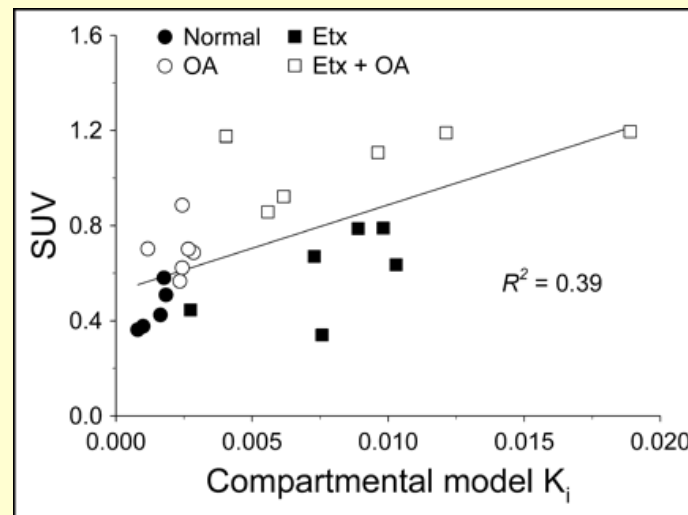
Erdi et al, J Nucl Med 2004

Use respiratory instructions if you can
Even better: do respiratory gating when needed

Additional sources of bias in SUV measurements (2)

- SUV is a crude estimate of the metabolic rate of glucose

$$\text{SUV } K_i = \frac{\text{tumour}(t) - \text{unmetabolized FDG}}{\int_0^t \text{AIF}(t) dt} \sim \text{injected dose / patient mass}$$



Chen et al, J Nucl Med 2004

Towards simplified kinetic analysis...
(but not yet practical enough for routine)

Hunter et al J Nucl Med 1996, Sundaram et al J Nucl Med 2004, Hapdey et al J Nucl Med 2011

2. Variability of SUV estimates

- Large variability in patient preparation, acquisition and processing protocols

- injected activity : 259-740 MBq (7-20 mCi)

patient preparation

- post-injection scan time : 45-90 min

- scanning time: 2-7 min/bed position

data acquisition

- reconstruction algorithm: 2D OSEM, FORE+OSEM, 3D OSEM, RAMLA with or w/o post-filtering

image reconstruction

- SUV estimates: SUVmax (91%), meanSUV (12%)

quantification

... not to mention (usually smaller effects):

- duration of fasting
- blood glucose level control
- CT technique
- management of diabetic patients
- voxel size
- ...

Graham et al J Nucl Med 2011, Beyer et al J Nucl Med 2011

Reducing the variability in SUV estimates

Standardization of Quantitative Imaging: The Time Is Right, and ^{18}F -FDG PET/CT Is a Good Place to Start

Buckler and Boellaard J Nucl Med 2011

Many efforts in that direction, e.g.:

- EANM protocol guidelines *Boellaard et al Eur J Nucl Med Mol Imaging 2010*
- Japanese guidelines *Fukukita et al Ann Nucl Med 2010*
- SNM action to establish consensus protocols
- ...

Word of caution: standardization should not be performed at the expense of accuracy (e.g., uptake time conveniently set to 60 min but suboptimal)

3. Going beyond SUV

- SUVmax : 1 tumour mass represented by 1 voxel value. Is that reasonable ?

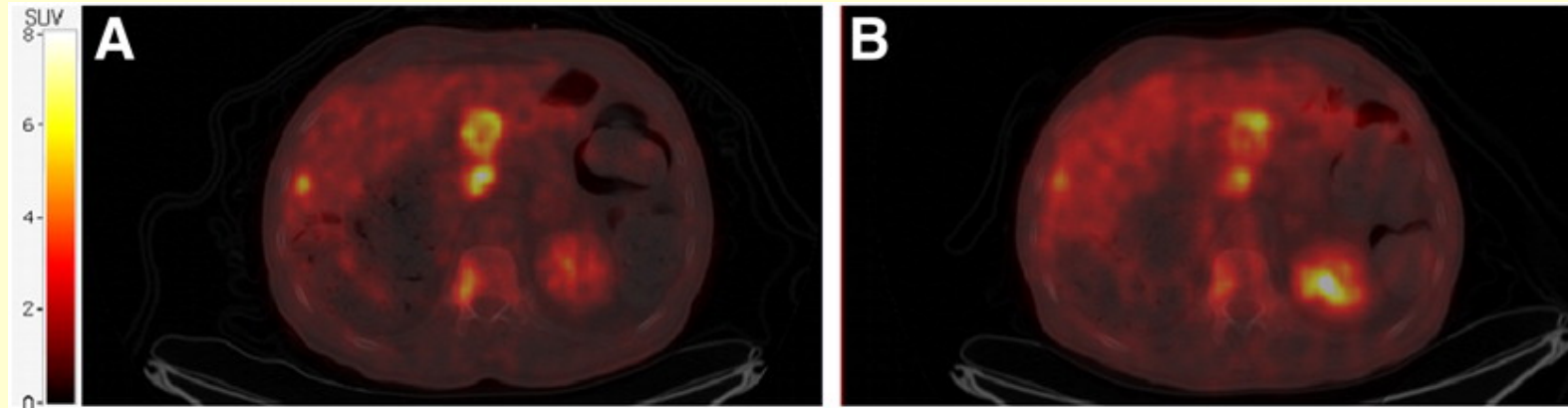


Smoothing embedded within
image reconstruction:
SUVmax can actually be seen as
a locally averaged SUV

- More comprehensive tumour characterization could be used, e.g. parametric imaging, texture analysis, or pattern recognition

Example 1: Imaging tumour response using parametric imaging

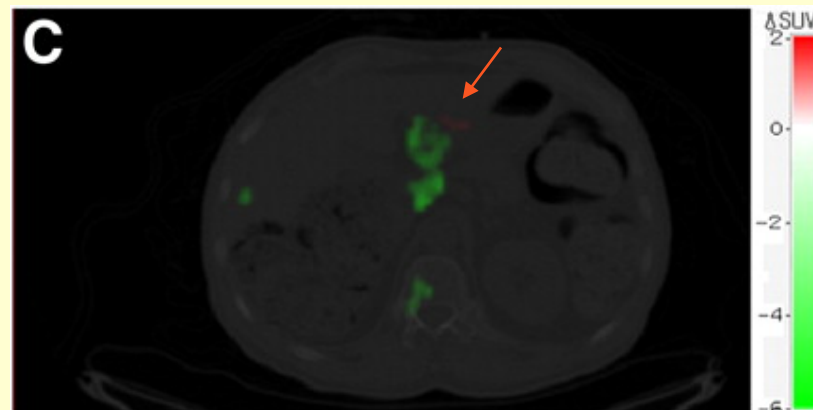
- Seeing heterogeneous tumour response



Baseline t0

t0 + day 14

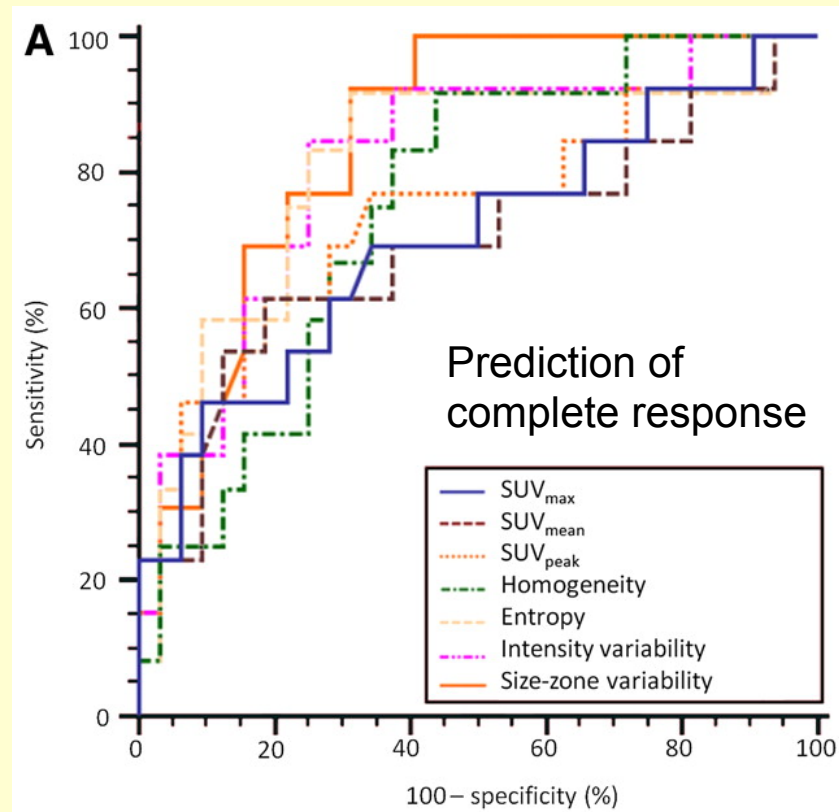
Metastatic colorectal cancer patient treated with chemotherapy



Necib et al J Nucl Med 2011

Example 2: Characterizing tumour heterogeneity

- Heterogeneity of tumours measured by textural features at baseline better might predict tumour response than baseline SUV



Esophageal cancer patients treated with radiochemotherapy

Tixier et al J Nucl Med 2011

Conclusions

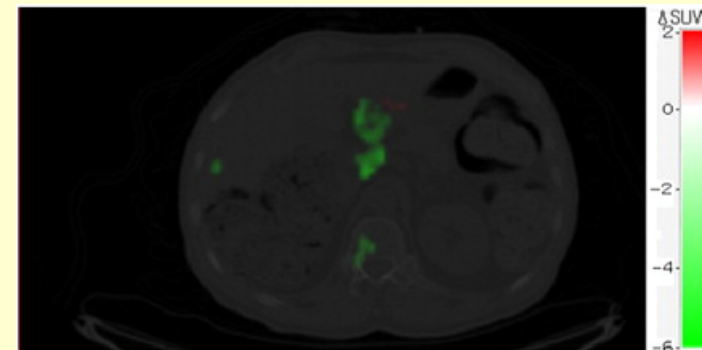
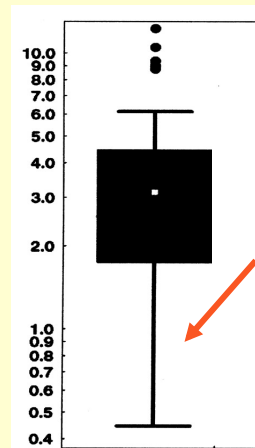
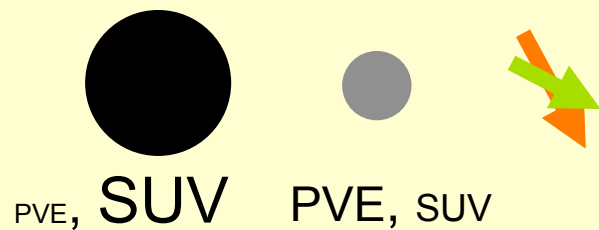
- FDG PET/CT is an admirable tool in oncology and has proven extremely effective
- SUV is neither Silly nor Smart* but is rather a
Simple Useful Value
- Advances in understanding bias (especially the tricky role of PVE) and corrections are still needed
- SUV still needs an extra level of standardization (S²UV) across centers
- Efforts to go beyond SUV (simplified kinetic analysis, parametric imaging, texture analysis, pattern recognition) should be pursued

* Visser et al J Nucl Med 2010

Take home message

1. Better control of errors in SUV estimates
2. Better standardization of FDG PET procedures
3. Going beyond SUV

should allow us to make the most of FDG PET in oncology and greatly increase the statistical power of multicentric studies and meta-analyses



Slides soon available on <http://www.guillemet.org/irene>