Partial volume correction in oncology body applications

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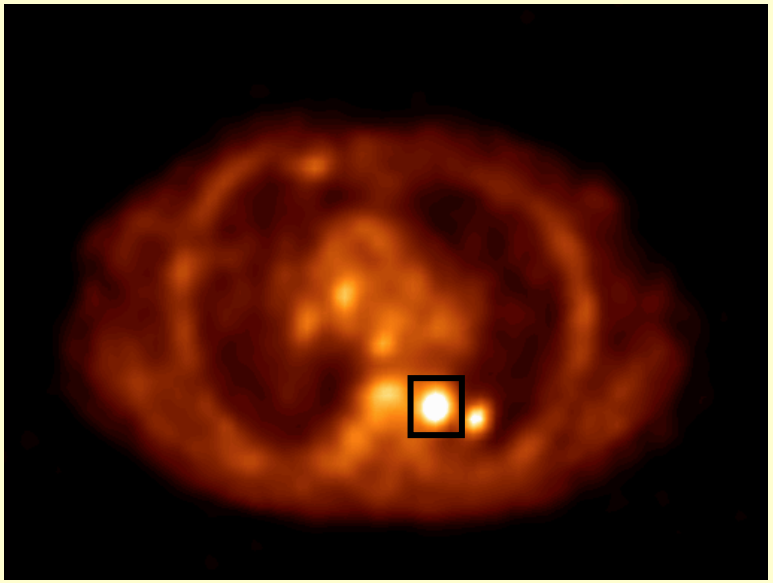
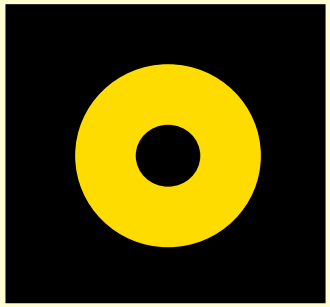
Outline

- Impact of partial volume in the specific context of oncology
- Four hints to reduce partial volume in oncology PET images
- Explicit partial volume corrections applicable in oncology
- Partial volume in oncology PET: friend or foe?

Impact of partial volume in oncology (1)

- Visually: partial volume can hide necrotic regions in tumors





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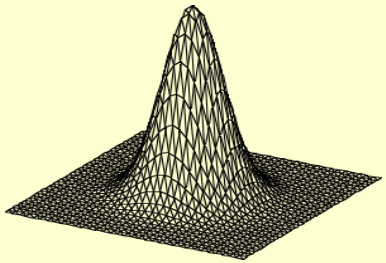


point spread function of
the imaging system

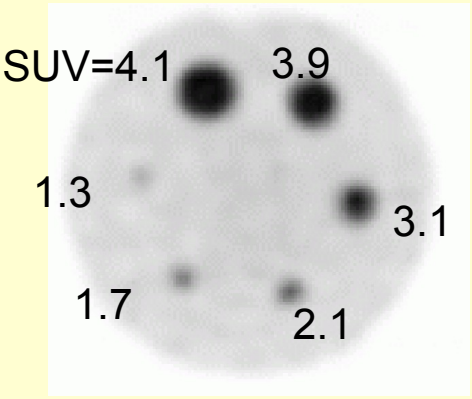
$=$

Impact of partial volume in oncology (2)

- Quantitative: bias in the SUV because of spill-out and spill-in affecting the uptake measurement

$$SUV = \frac{\text{activity estimate (kBq/mL)}}{\text{injected dose (kBq) @ scan time} \,/\, \text{“patient weight (g)”}}$$

Same activity concentration in each sphere (10, 12, 16, 22, 28, 34 mm in diameter)

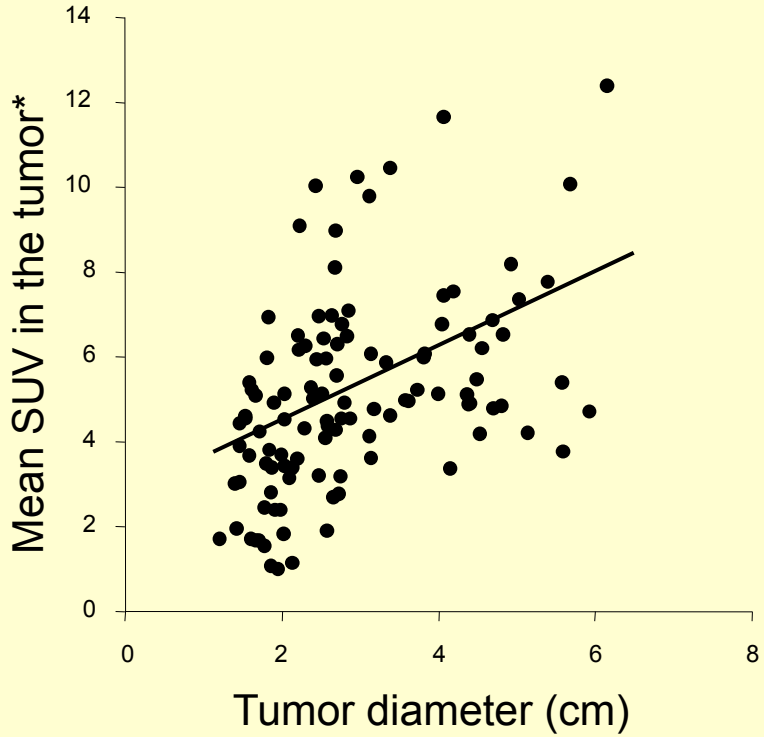


True SUV ~4

Same or different SUV?

Do it yourself…

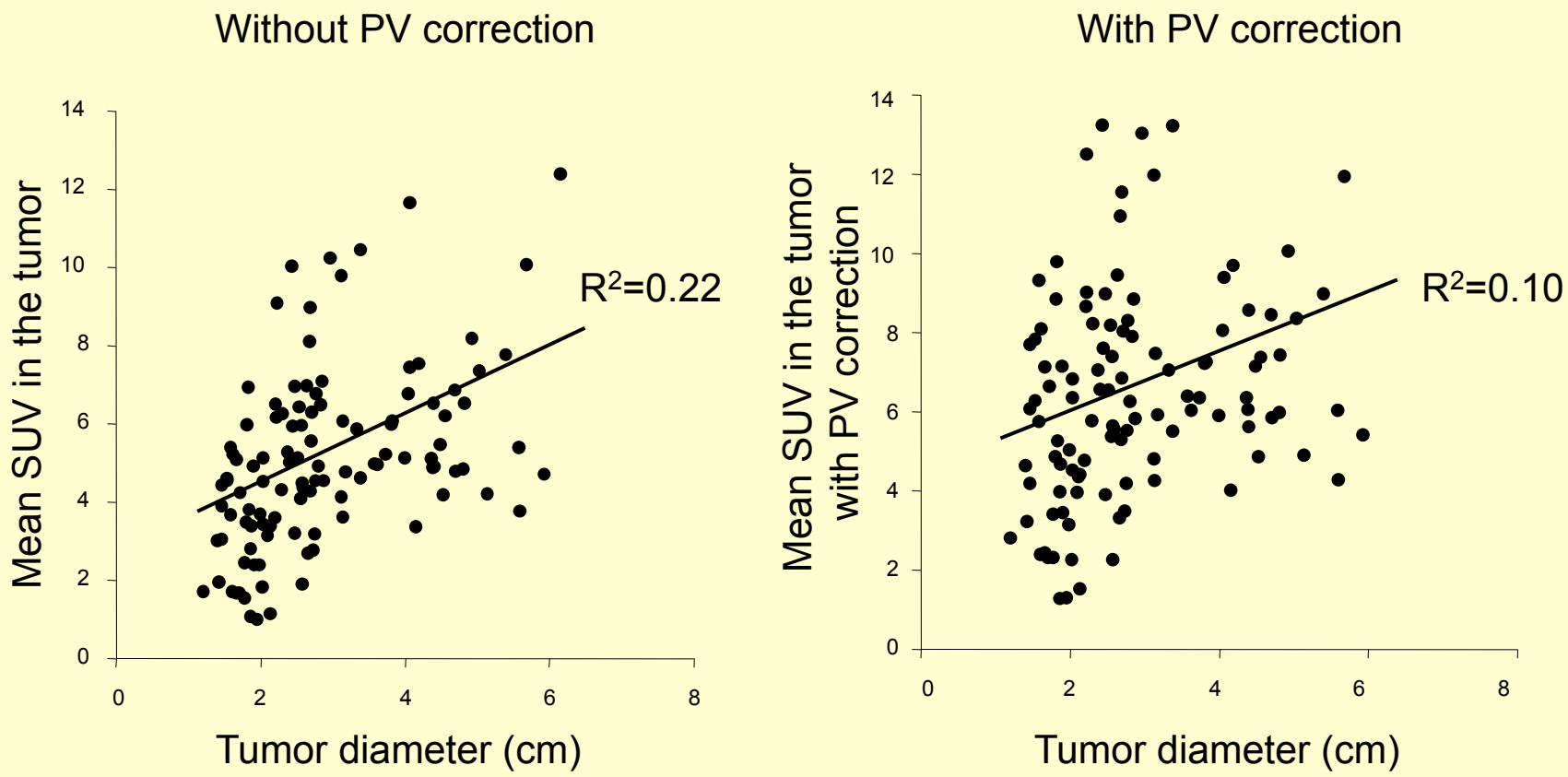
- Plot SUV = f (tumor size) for a set of tumours



Not that bigger tumors are always more metabolically active, but bigger tumors are less affected by partial volume effect !

* Mean in a tumor volume obtained using the method described by Nestle et al, J. Nucl. Med. 2005

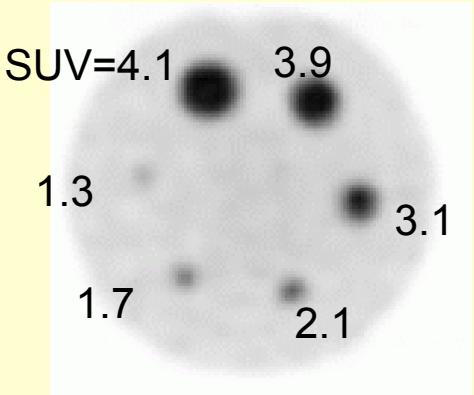
Proof



Correcting for partial volume reduces the correlation between tumor size and SUV

First take-home message

• SUV cannot be trusted in small tumors (less than 2 to 3 FWHM in the reconstructed images, ie < 2-3 cm diameter in PET)



• **In small tumors, SUV does not only reflect the uptake, but also reflects the metabolically active volume**

What can we do to deal with partial volume?

2 options:

- Reducing partial volume effect
  - by improving spatial resolution
  - by using finer sampling

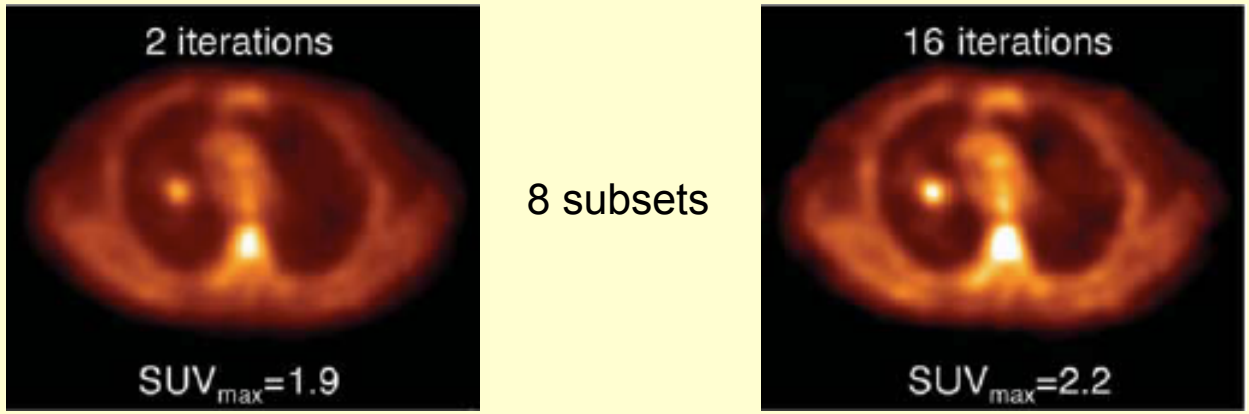
But partial volume effect will always remain present in the images because of limited spatial resolution and image sampling

It also affects MR and CT images !

- Correcting for partial volume effect

Hints to reduce partial volume effect in oncology images (1)

• Use of a sufficient number of iterations to achieve better spatial resolution, even if the image quality gets deteriorated: quantitative accuracy is improved



Hints to reduce partial volume effect in oncology images (2)

- Being aware of the impact of the SUV measurement method

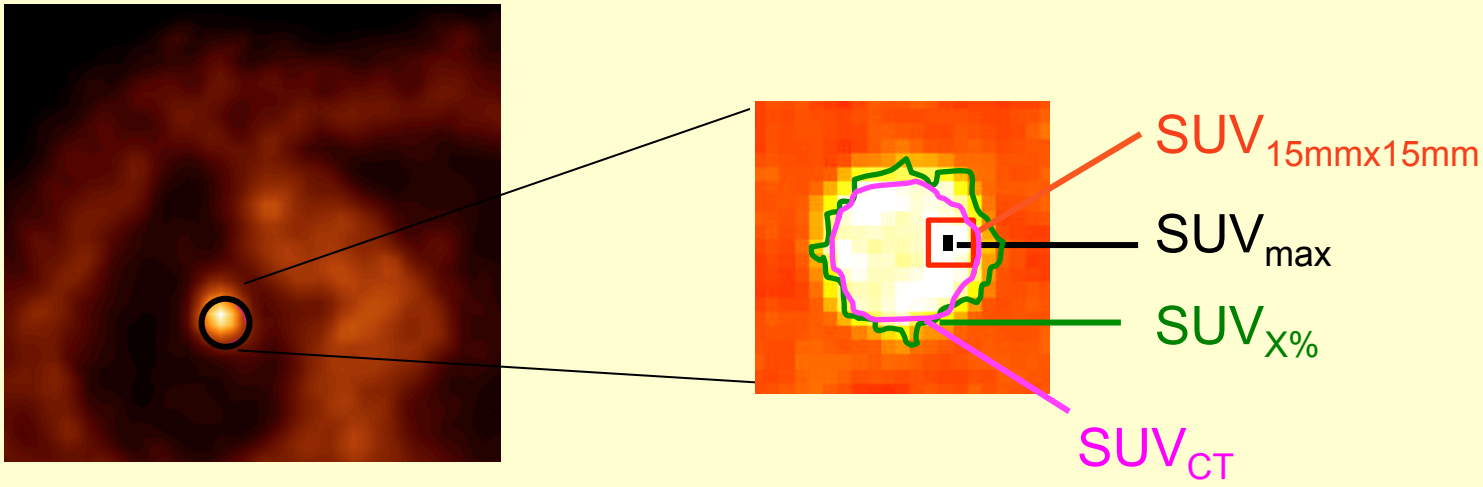
SUV_{max} =4.9

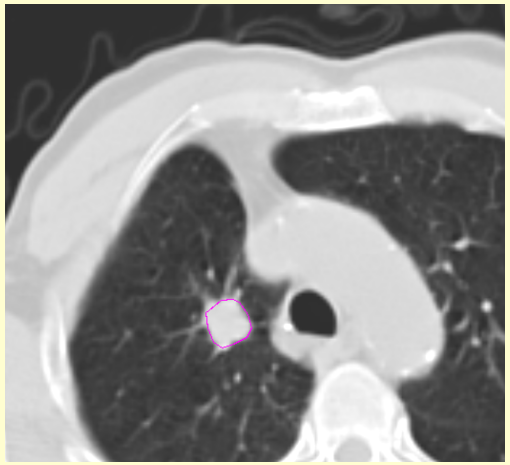
$SUV_{75\%}$ =4.1

$SUV_{50\%}$ =3.7

SUV_{15*15}=3.1

SUV_{mean}=2.6

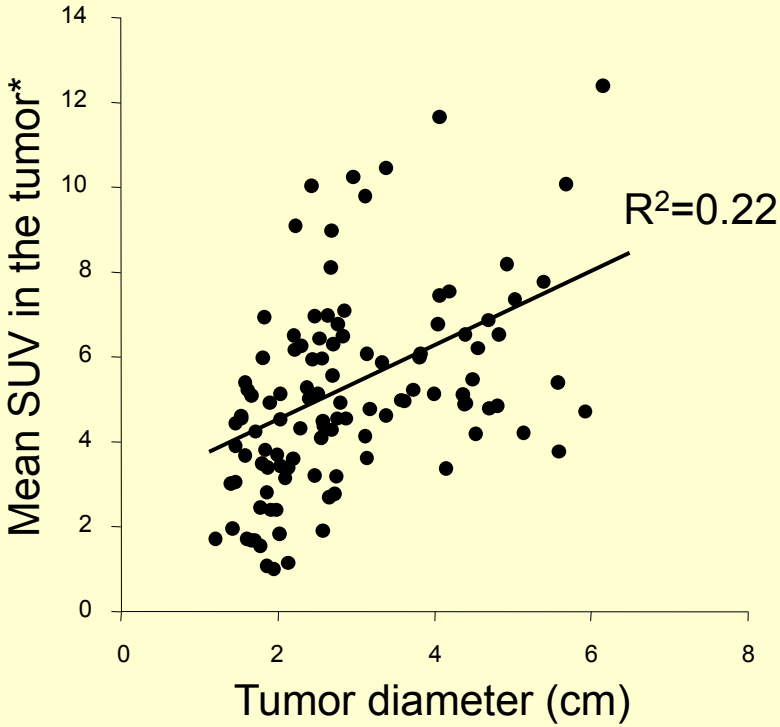


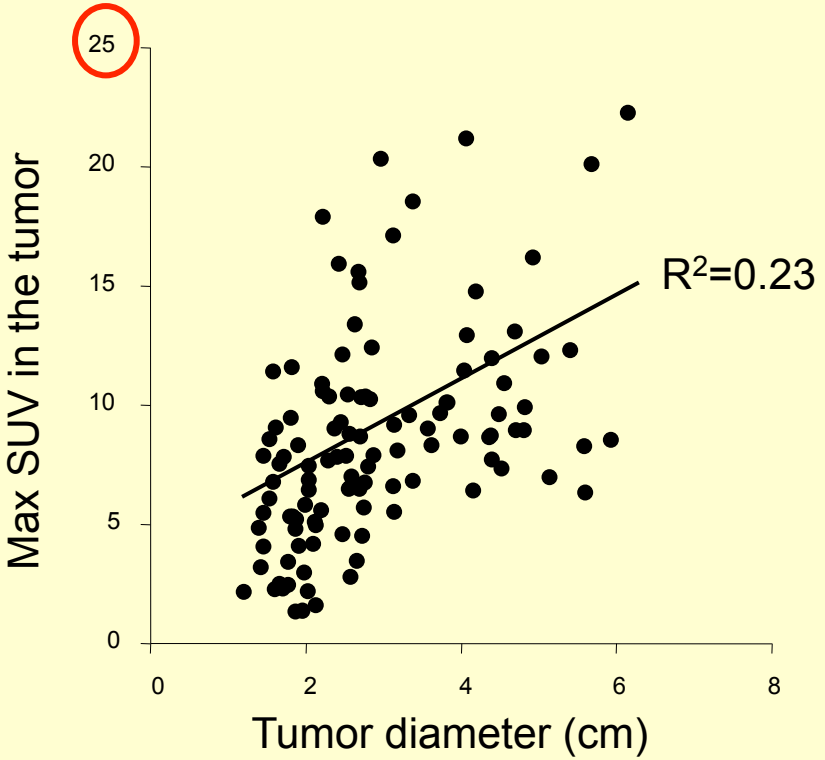


Hints to reduce partial volume effect in oncology images (3)

- Which one is best?

No easy answer !





Even SUV_{max} is affected by partial volume effect

* Mean in a tumor volume obtained using the method described by Nestle et al, J. Nucl. Med. 2005

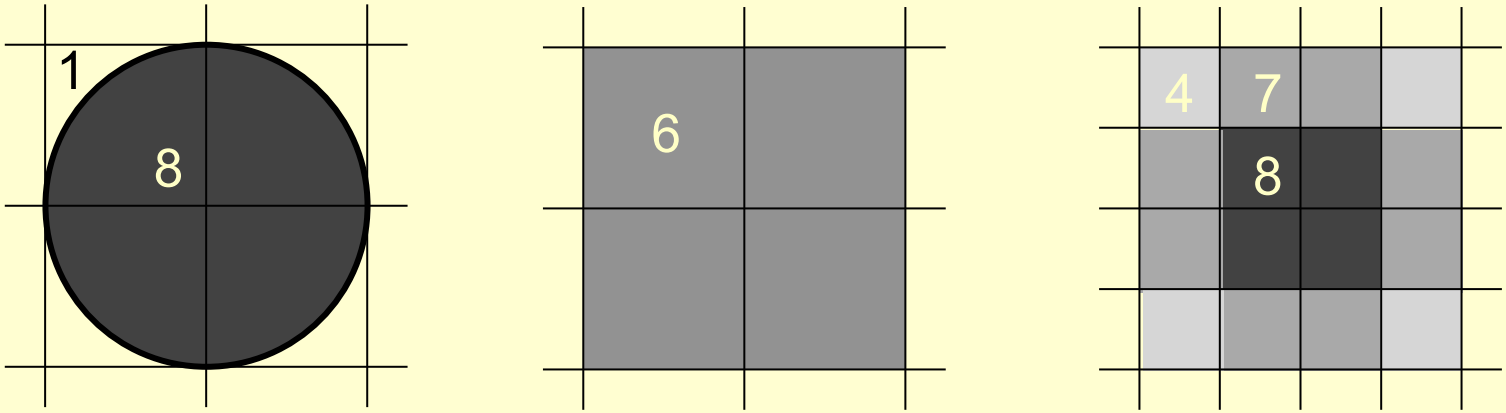
Hints to reduce partial volume effect in oncology images (4)

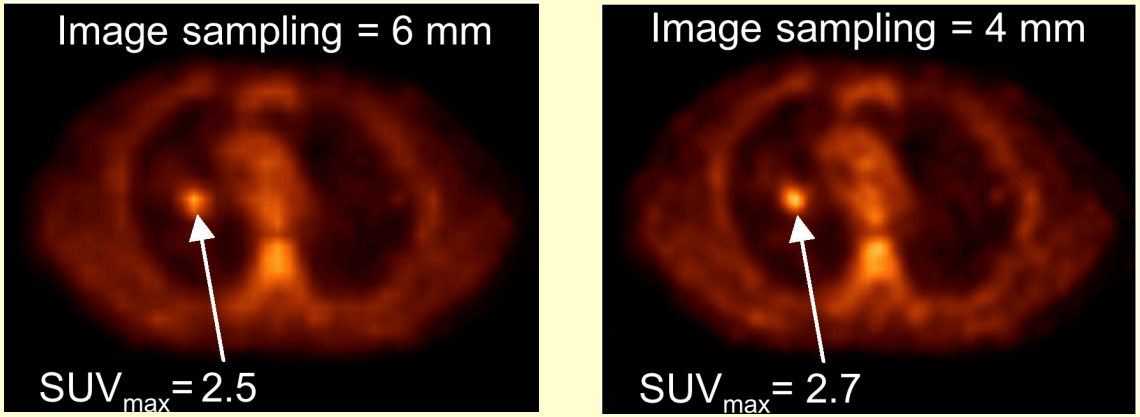
- Using a reconstruction accounting for sources of blur if available

See Dan's talk

Hints to reduce partial volume in oncology images (5)

- Use small voxels to reduce the tissue fraction effect





But limitation due to the machine,
noise can be a problem

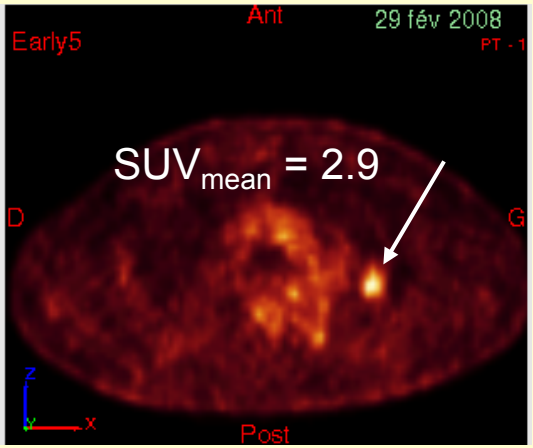
Explicit partial volume corrections

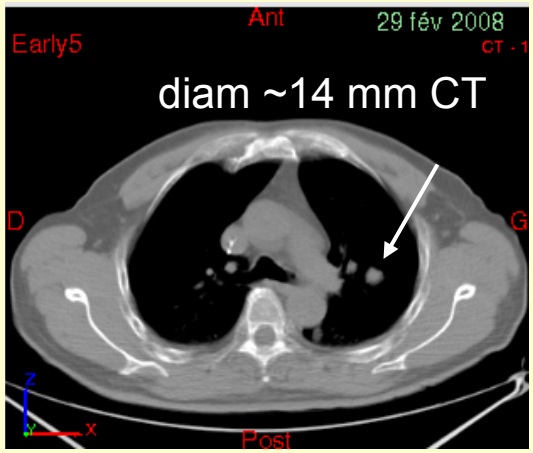
• Vendor offer: extremely limited, probably nothing available on your console

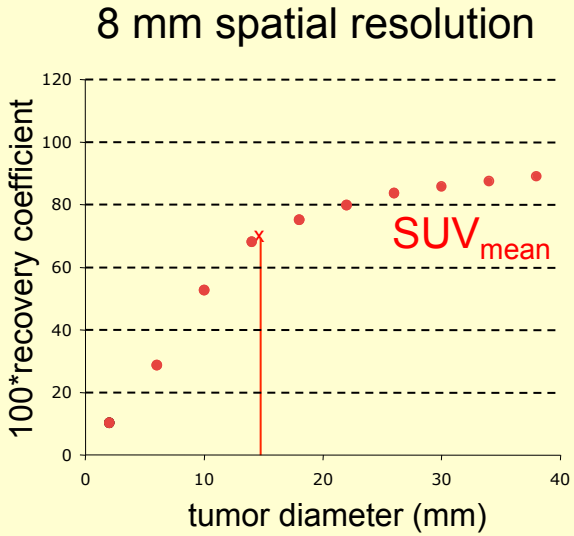
• You can still do something remotely and then try convince your vendor to get it available on your console

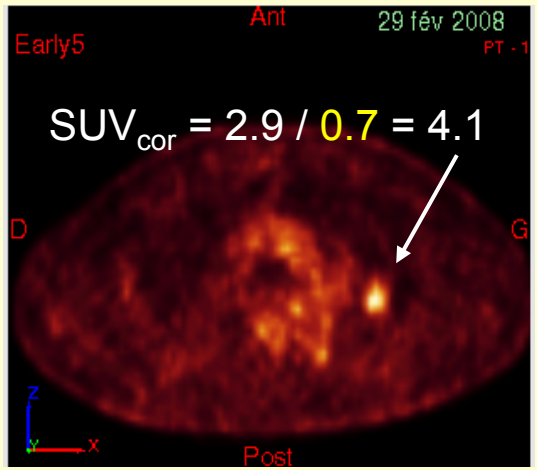
Easiest approach: using a recovery coefficient

- Method



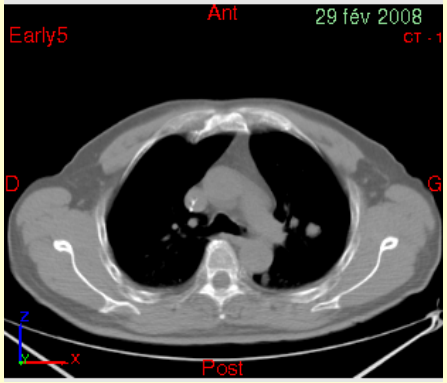




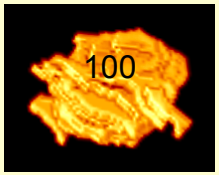


How to get the recovery coefficient accurately?

- Ideally

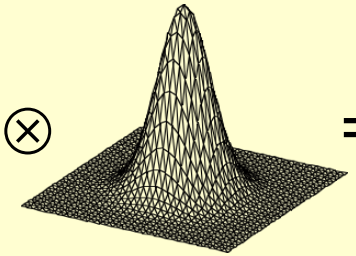


Draw the tumor contour in 3D



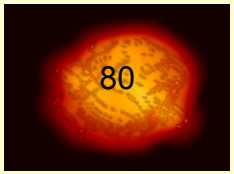
3D tumor shape

⊗



PSF of your imaging system

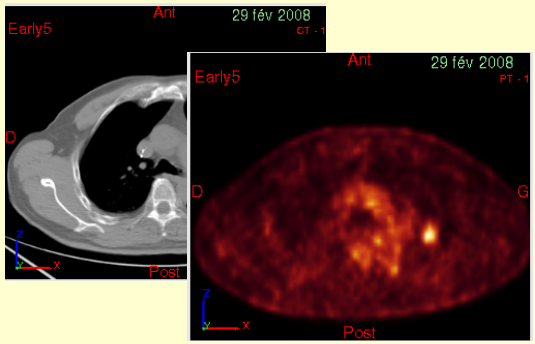
=



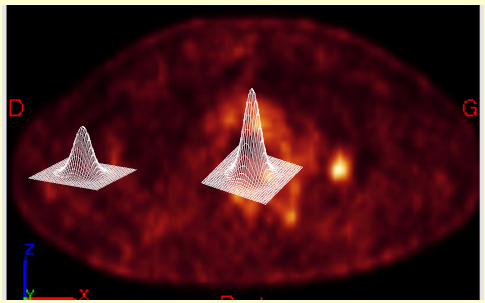
RC
= 80/100
= 0.8

but

How to best delineate the tumor ?

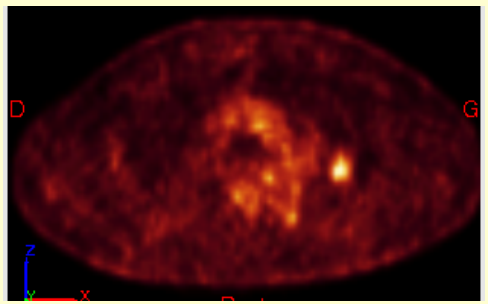


CT ? PET ?
Which algorithm ?



Which PSF ?

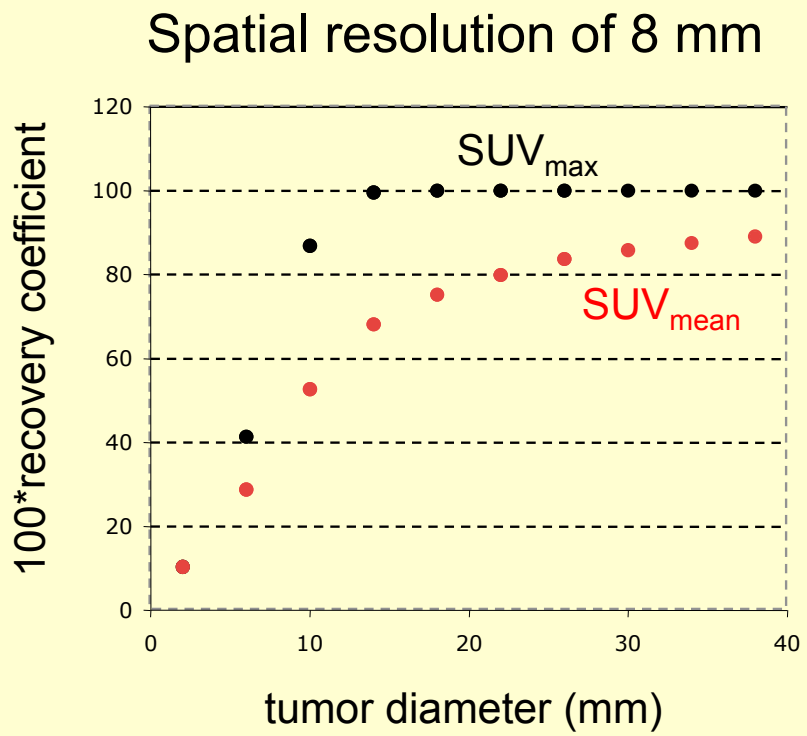
Which background activity?



SUV_{cor}
$=(SUV-SUV_{bgd})/RC+SUV_{bgd}$

How to get the recovery coefficient more easily?

- Use predefined abacus appropriate for:
  - spherical and non-necrotic tumors
  - a given spatial resolution in the images
  - a given measurement method (SUV_{mean}, SUV_{max}, etc)



More sophisticated approaches

• Many methods have been recently described for partial volume correction, but **there is still a lack of clinical validation**

e.g., Boussion et al Phys. Med. Biol. 2006, Teo et al J. Nucl. Med. 2007, Kirov et al Phys. Med. Biol. 2008, Tylski et al J. Nucl. Med. 2010

Tentative recommendations:

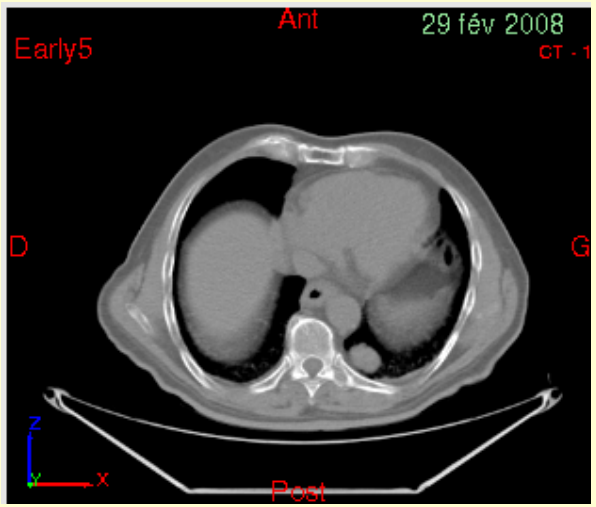
1/ Validation of the method(s) first on your own data using a simple phantom experiment (Jaszczak phantom with spheres)

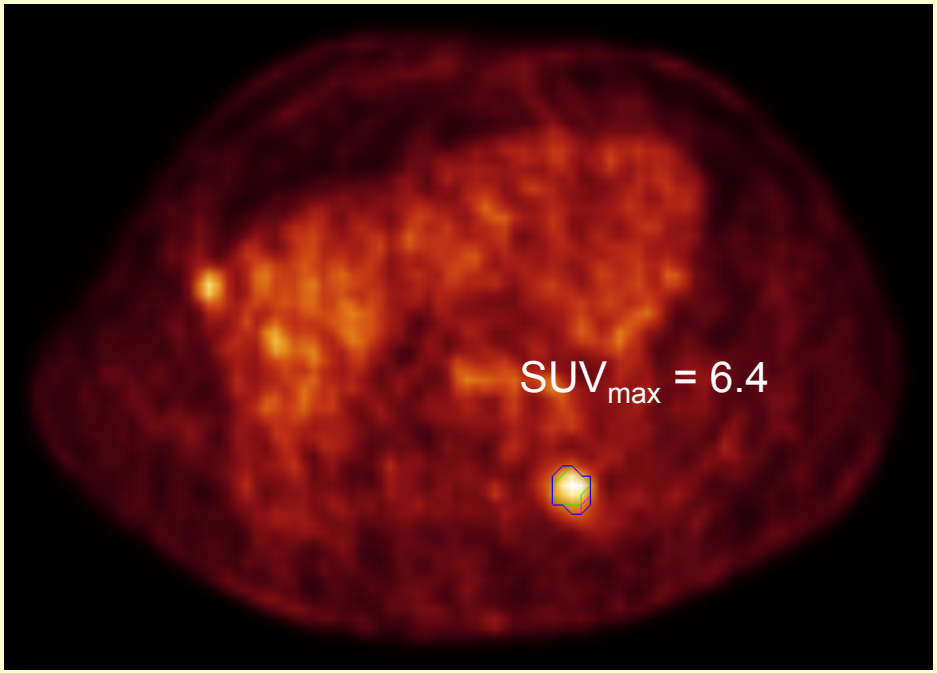
2/ Use the method(s) that passed validation, and look at the resulting SUV.

Considering SUV with and without PV correction gives you an indication about how the SUV can be trusted.

More sophisticated approaches

- Example





	SUV	SUV$_{cor}$	Volume (mL)
Max	6.4	-	-
Mean in a 40% of max isocontour	3.3	4.2	5.2
Mean in a contour accounting for bgd activity*	3.4	4.5	4.4
Mean in a contour ajusted iteratively#	3.1	3.8	6.7

* Nestle et al, J Nucl Med 2005, 46:1342–1348.
# Black et al, Int J Radiat Oncol Biol Phys 2004,60:1272–1282

Partial volume effect in oncology PET: friend or foe?

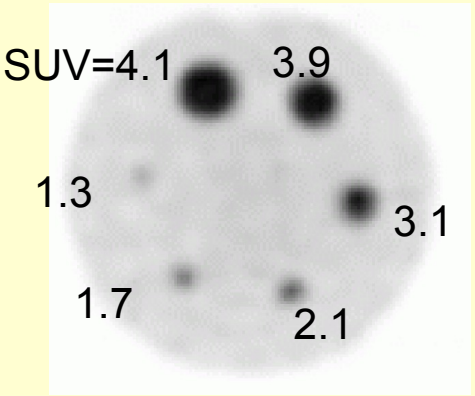
- Foe

- for SUV estimates

- for SUV-based tumor grading

unless grading needs to be based on both the glucose metabolic rate and the metabolically active tumor volume

Same activity concentration in each sphere



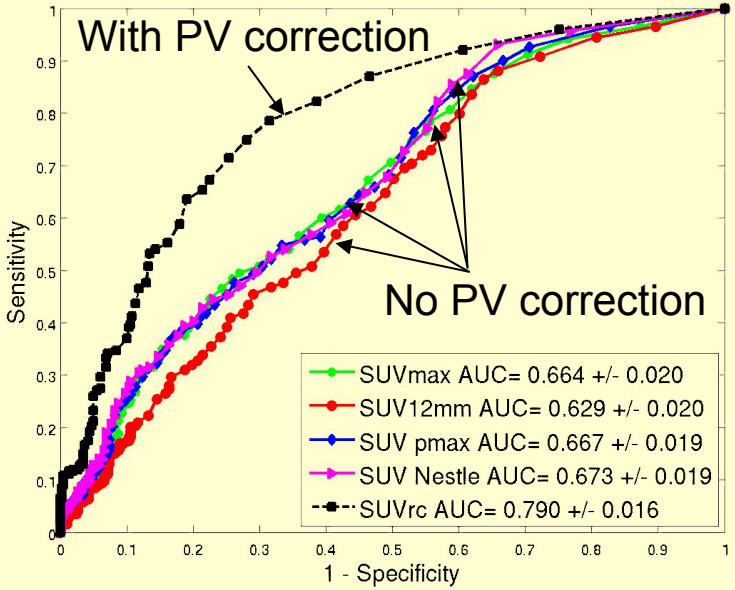
This is probably why SUV without PV correction is found to be useful for tumor grading and for predicting survival

Partial volume effect in oncology PET: friend or foe?

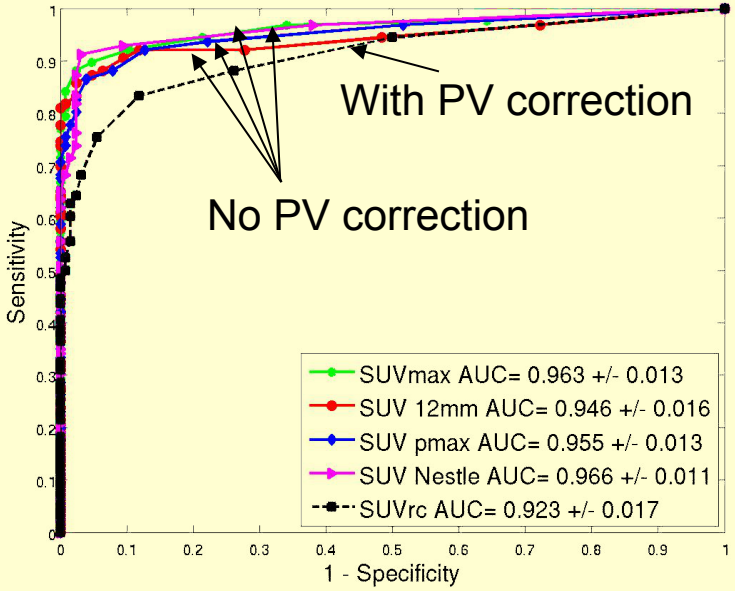
- Friend for patient monitoring ?

Monte Carlo simulations - 2 discrimination tasks :

Tumors with SUV change vs tumors without SUV change



Tumors with change in SUV or in volume vs tumors without any change



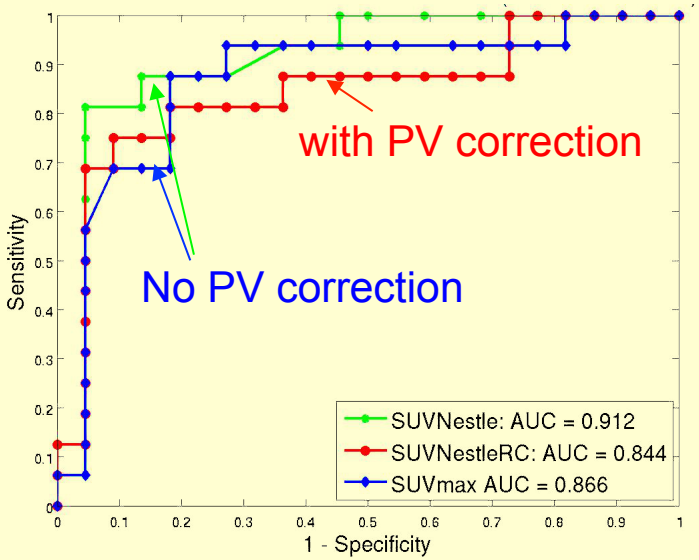
Partial volume correction helps detect SUV changes independent from other changes,
but **partial volume correction does not improve the detection of overall tumor changes** (in SUV, in volume, or in both)

Partial volume effect in oncology: friend or foe?

- Friend?

What is best to characterize tumor response ?
Change in glucose metabolic activity or metabolically active volume or both ?

Real data (patients with colorectal cancer, 56 tumors)
Changes between baseline and early PET (after 1 cycle chemotherapy)
Reference for responding / non responding classification : RECIST from CT acquired at least 4 weeks after the early PET



Including volume change information by using non-corrected SUV seems useful to assess the tumor response (tbc)

Conclusions

• Because of partial volume, usual SUV reflects both tumor uptake and tumor metabolically active volume.

• Partial volume corrections for oncology PET images become available but still need extensive validation in patients.

• The role of partial volume correction for SUV-based tumor staging and patient monitoring still need to be clarified.

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