# Advanced quantification in oncology PET

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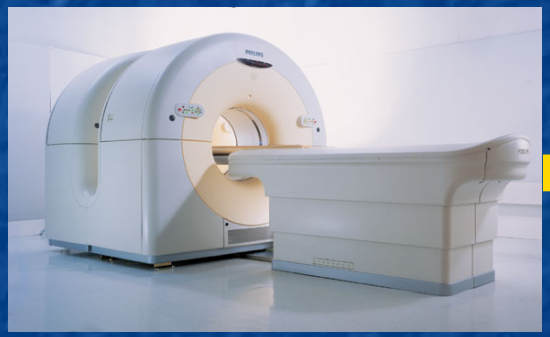
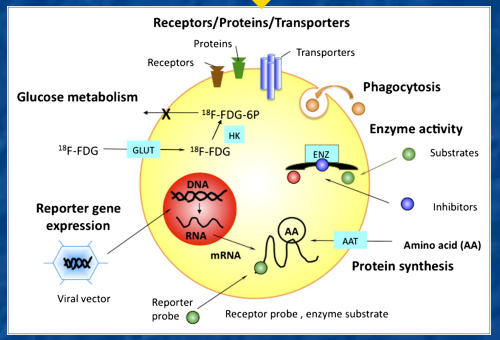
# Two steps



Radiotracer concentration (kBq/mL)

Static imaging
Dynamic imaging




- Glucose metabolism
- Metabolically active tumor volume
- etc…

# Quantification issues in oncology PET

- Tumor segmentation
- Identification of indices that best characterize the tumor in a specific context
- Interpretation of tumor changes during therapy
- Understanding the relationship between macroscopic parameters (from PET images) and microscopic tumor features

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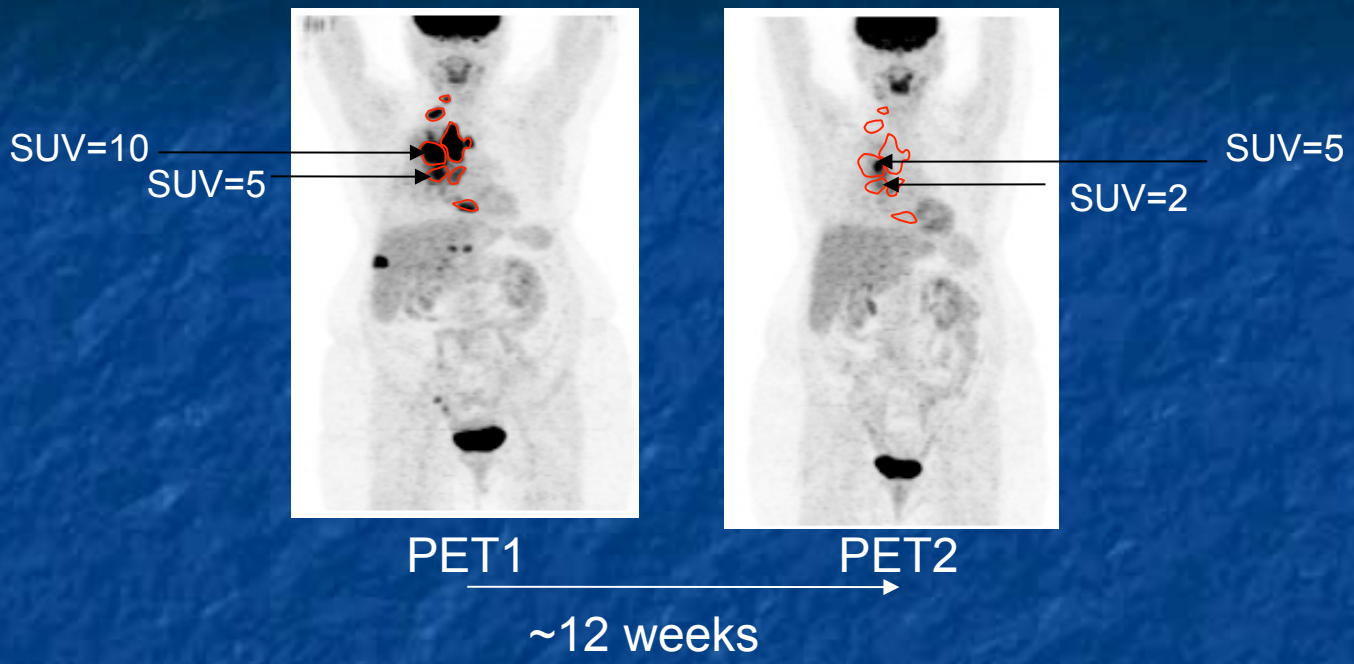
# Current quantification in oncology PET

Tracer uptake (kBq/mL)

$$\text{SUV (Standardized Uptake Value)} = \frac{\text{Tracer uptake}}{\text{Injected activity / patient weight}}$$

SUV ~ metabolic activity of tumor cells

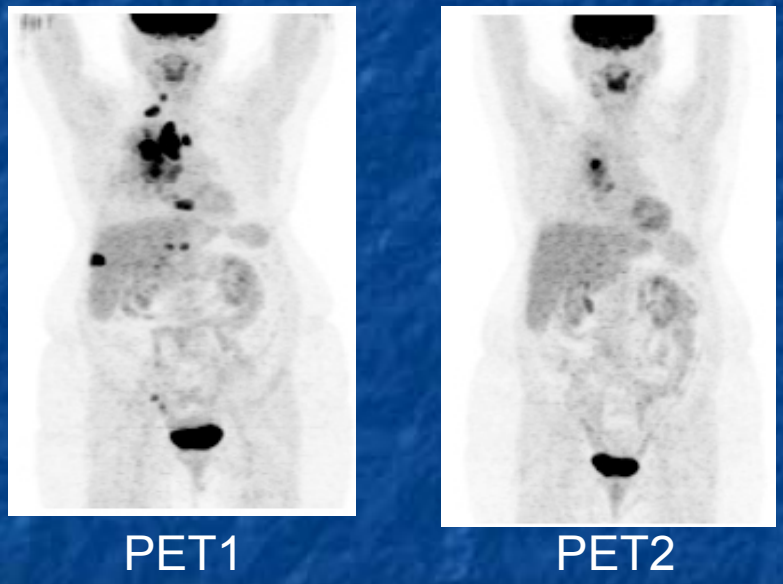
# Comparing 2 PET scans : current approach




- Need to identify and possibly delineate the tumors
- Each tumor = 1 single SUV
- Change compared to an empitical threshold (provided in recommendations such as EORTC, PERCIST)
- Tedious when there are many tumor sites

# A novel parametric imaging approach

Goal : Get an objective voxel-based comparison of 2 PET/ CT scans

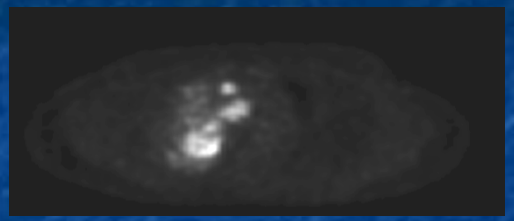


PET1 PET2

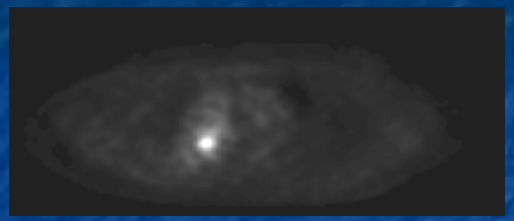
~ 12 weeks

# Main steps

1. PET image registration based on the CT associated with the PET scans

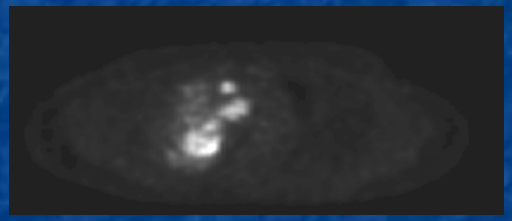


PET1

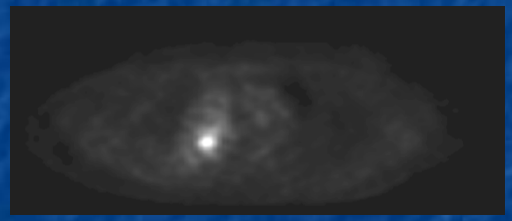


PET2

2. Voxel-based subtraction of the 2 image volumes



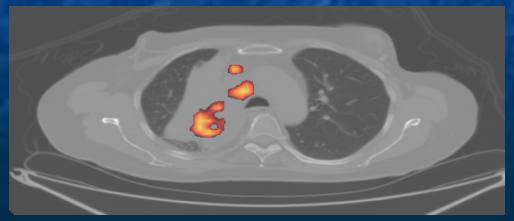
$- T_{21}$



=

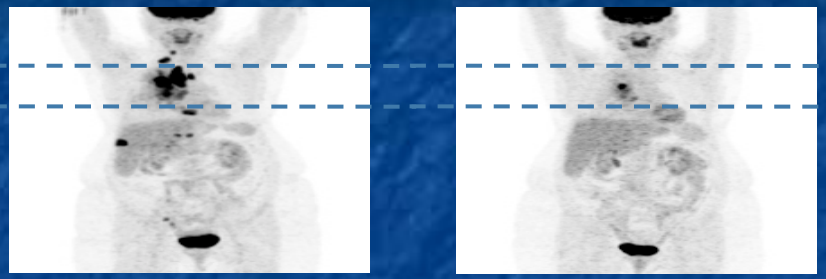
PET1 PET2 PET1-PET2’

3. Identification of voxels in which SUV significantly changed between the 2 scans using a biparametric analysis



# Step 1

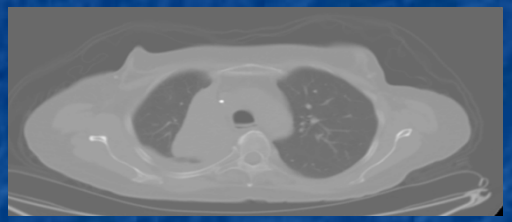
VOI selection



PET1 PET2

CT1 CT2

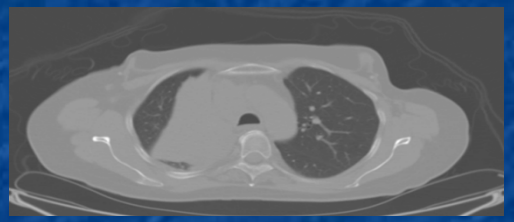
Identification of the transformation needed to realign the 2 CT



CT2

$T_{21}$

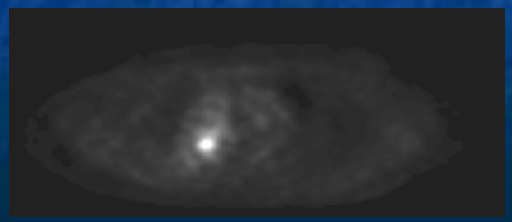
(rigid transform using Block Matching)



CT2

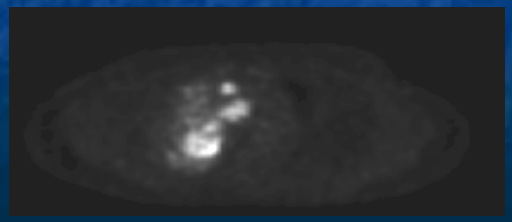
Registration of the PET volumes using the $T_{21}$ transformation

$T_{21}$



PET2

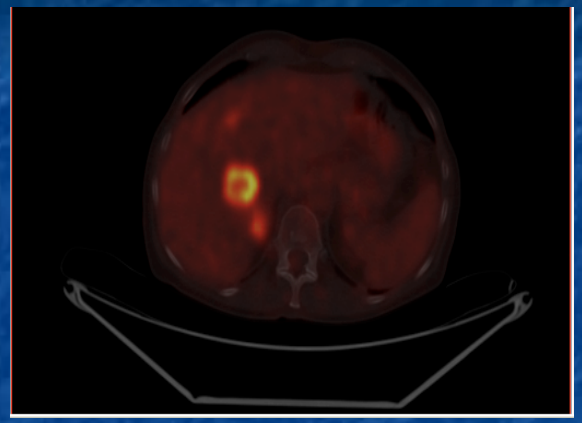
realigned with

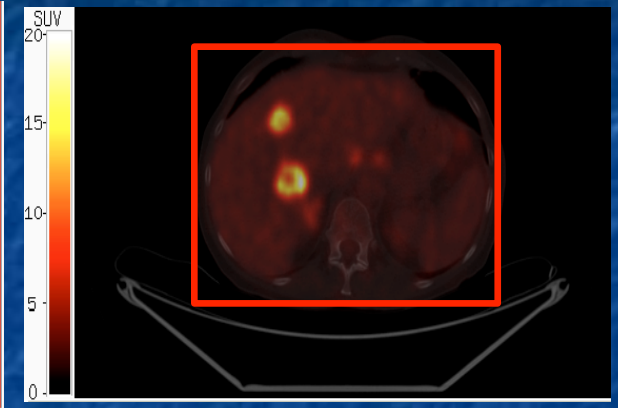


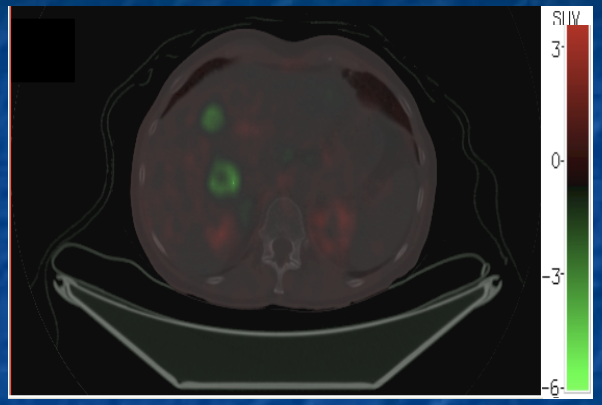
PET1

# Step 2

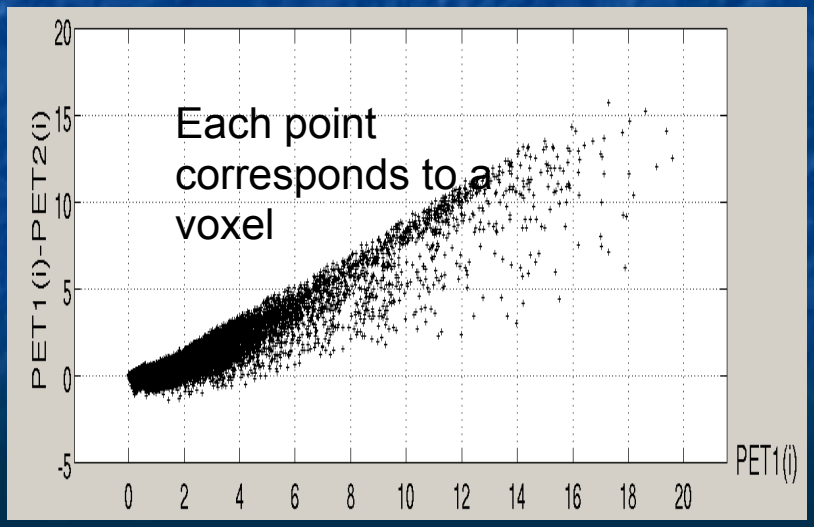
## Subtraction of the 2 realigned PET scans

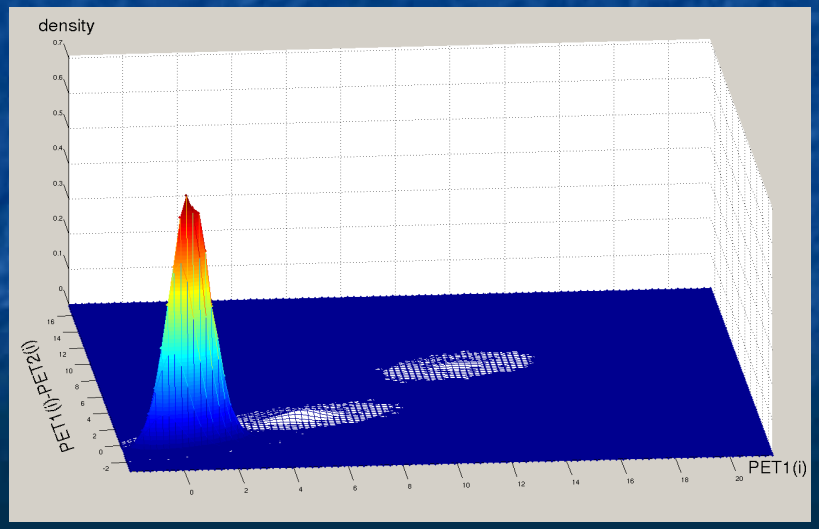




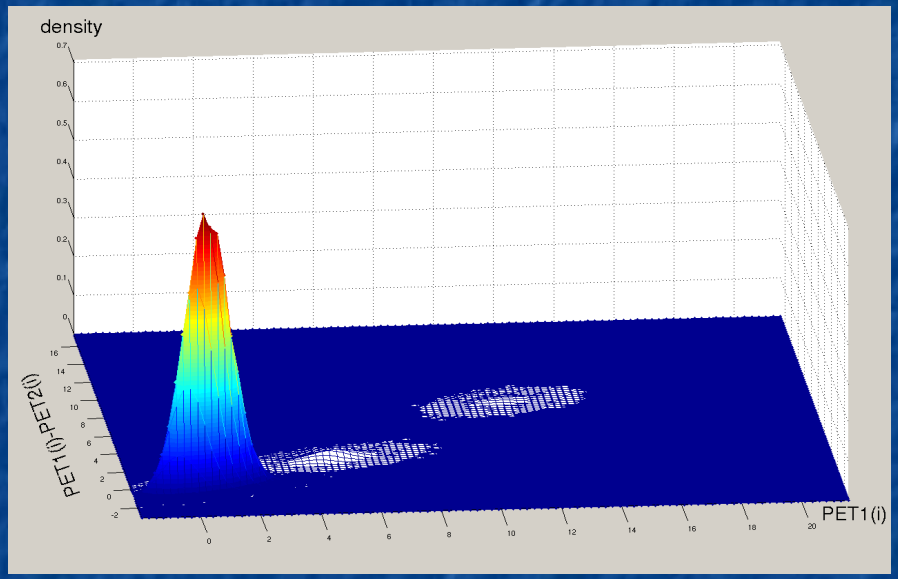

$T_{21}${PET2/CT2} - PET1/CT1 = $T_{21}${PET2} – PET1/CT1



# Step 3

Identification of the significant tumor changes in the 2D-space by solving a Gaussian mixture model




$$x_i \begin{bmatrix} \text{PET1(i)-PET2(i)} \\ \text{PET1(i)} \end{bmatrix}$$

$$f(x_i|\theta) = \sum_{k=1}^{K} p_k \, \phi(x_i|\mu_k,\Sigma_k)$$

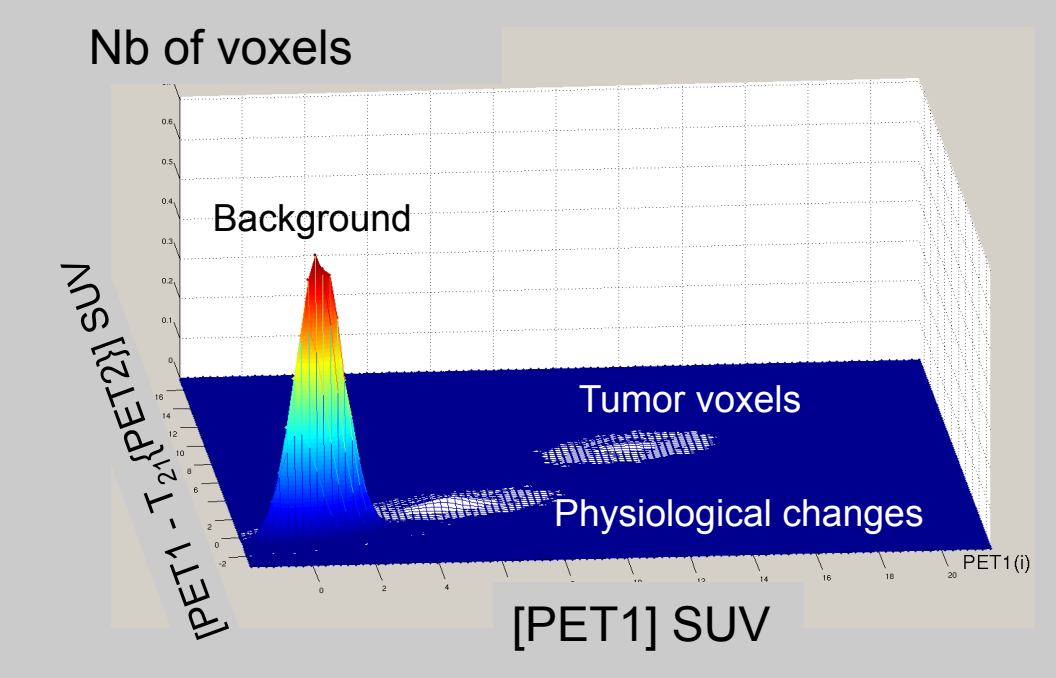
mixture density

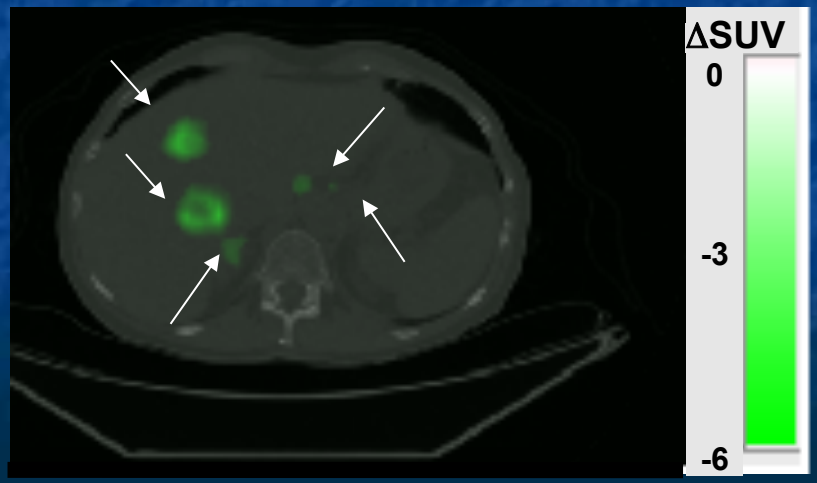
mixture parameters

2D Gaussian density

$\theta$ : vector of parameters ($p_1$, … $p_K$, $\mu_1$, ….$\mu_K$, $\Sigma_1$, … $\Sigma_K$)

# Step 3: results



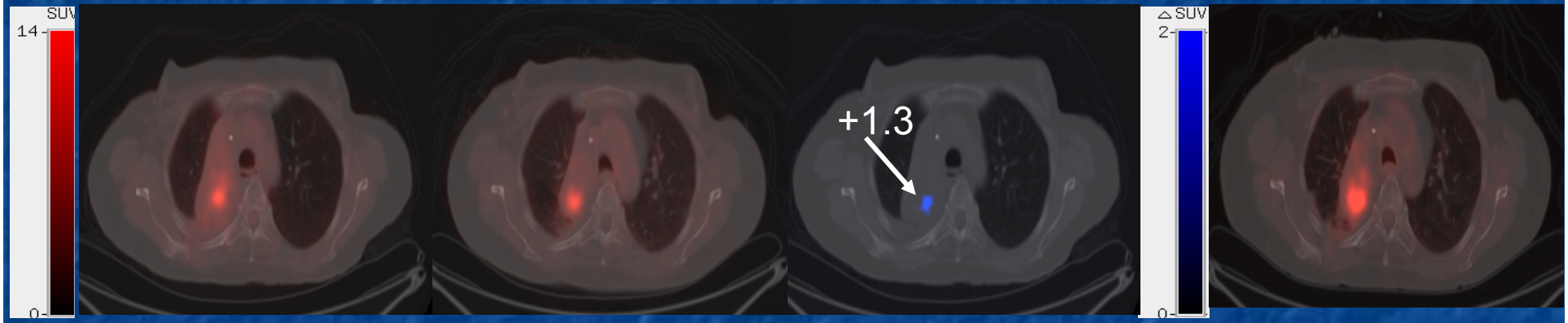

Parametric image

ΔV: volume with a significant change

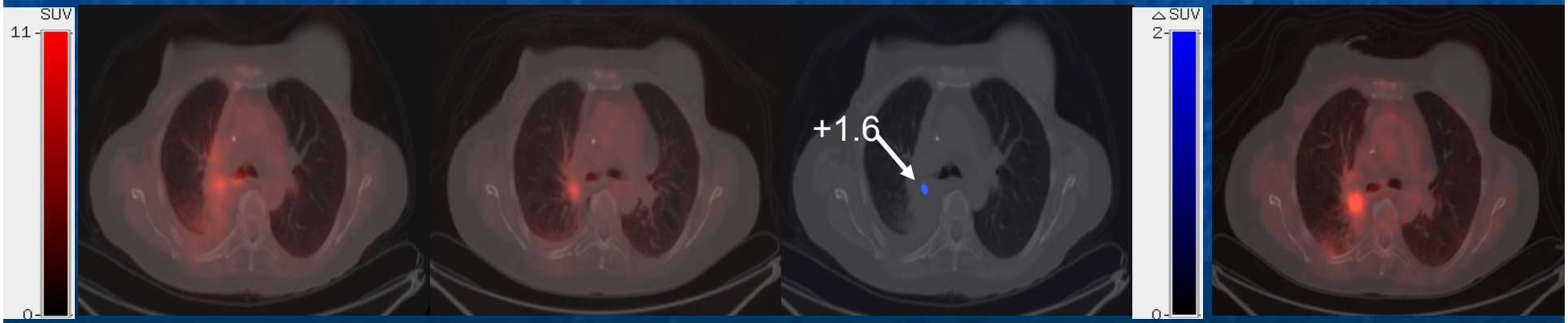
ΔSUV: change magnitude

# Example

## Identification of small tumor changes (lung cancer)



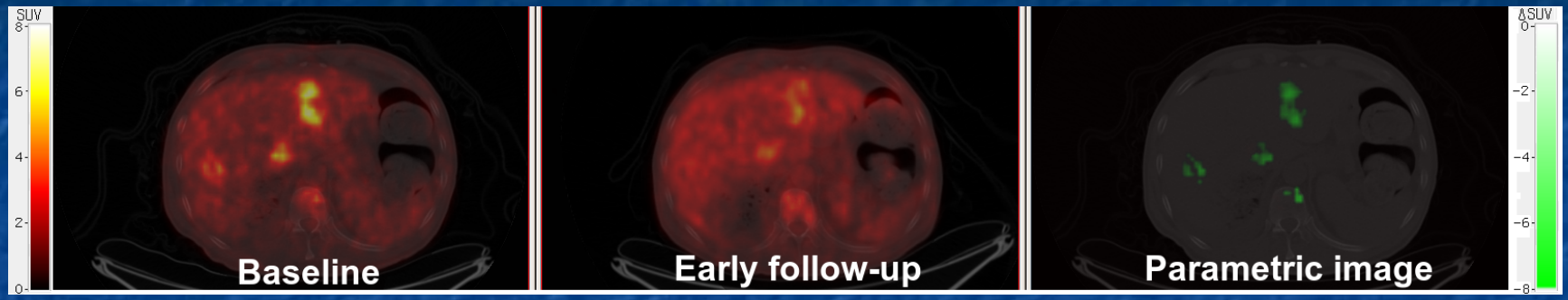

PET1 | $T_{21}${PET2} | $T_{21}${PET2} - PET1 after solving the GMM | PET3




PET1 | $T_{21}${PET2} | $T_{21}${PET2} - PET1 after solving the GMM | PET3

# Clinical validation : 28 patients with metastatic colorectal cancer

78 tumors with 2 PET/CT (baseline and 14 days after starting treatment)




| | NPV | PPV | Sensitivity* | Specificity |
|---|---|---|---|---|
| EORTC | 91% | 38% | 85% | 52% |
| PI | 100% | 43% | 100% | 53% |

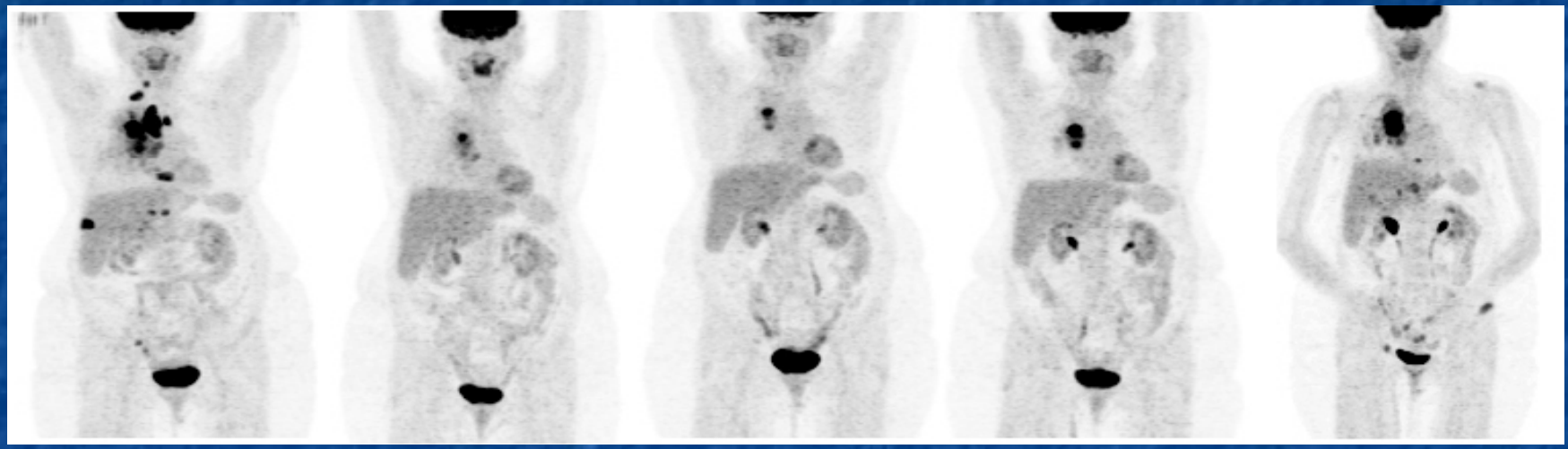
* for detecting lesions

- All tumors identified as progressive tumors at D14 were confirmed as such 6 to 8 weeks after based on CT (RECIST criteria)
- Among the 14 tumors identified as progressive tumors by RECIST criteria, 12 were identified as such at D14 using PI while only 2 were identified using EORTC criteria (SUVmax)

*Necib et al, J Nucl Med 2011*

# Comparing more than 2 PET/CT scans

## Longitudinal study

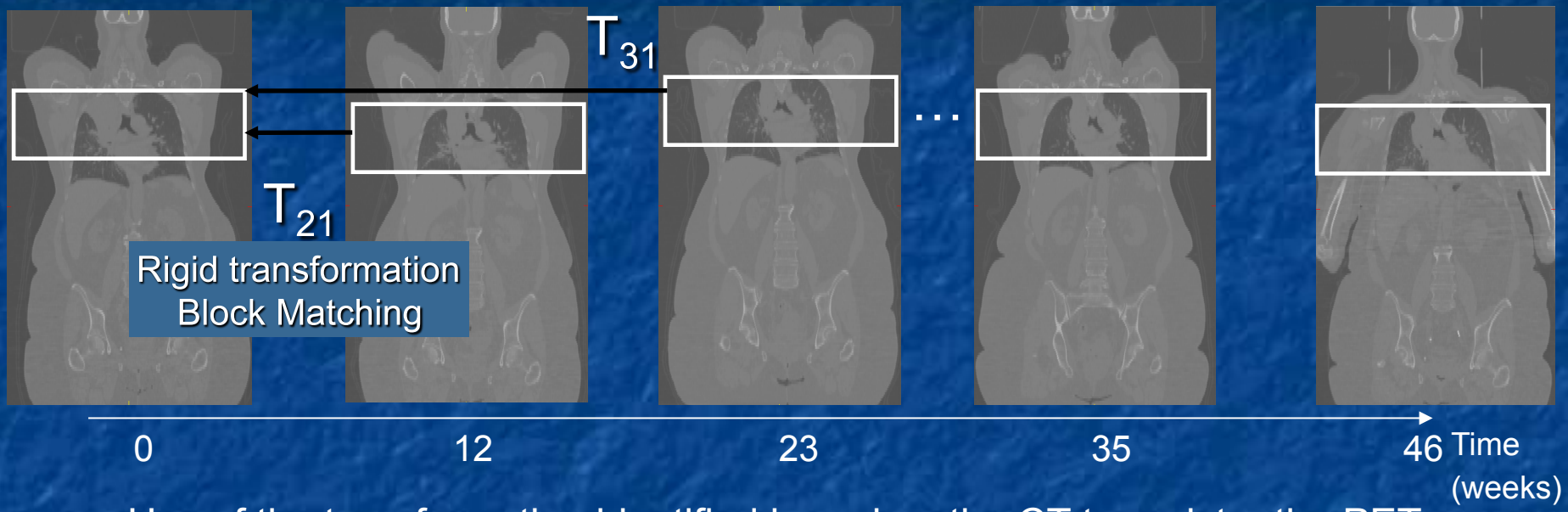



Problem : characterize the tumor changes

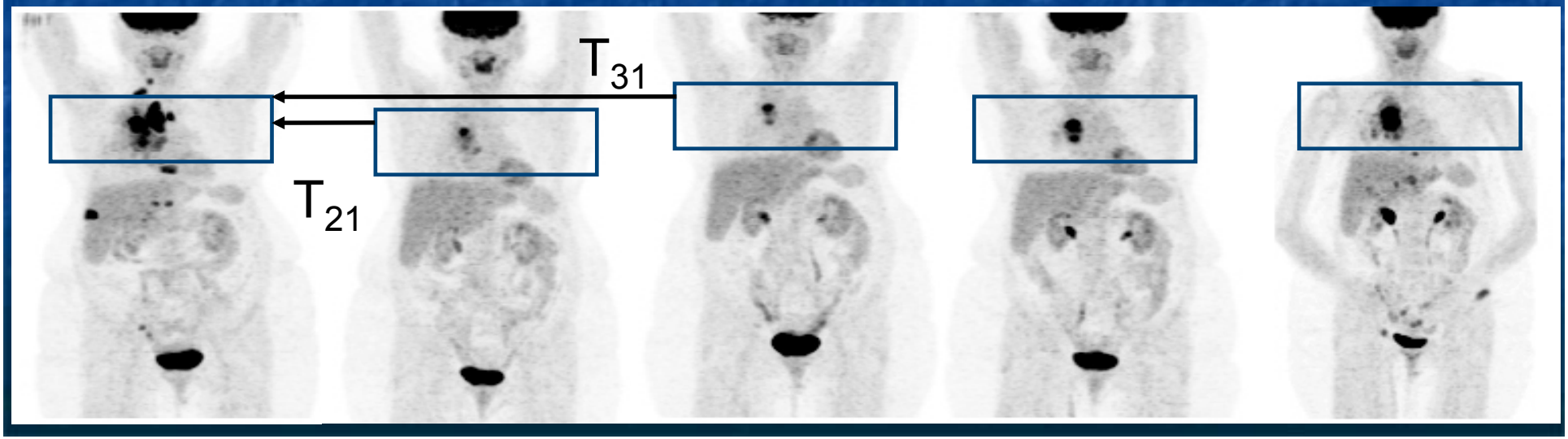
No method, each scan is usually compared only to the previous one

# A parametric imaging solution

First step: PET image registration based on the associated CT



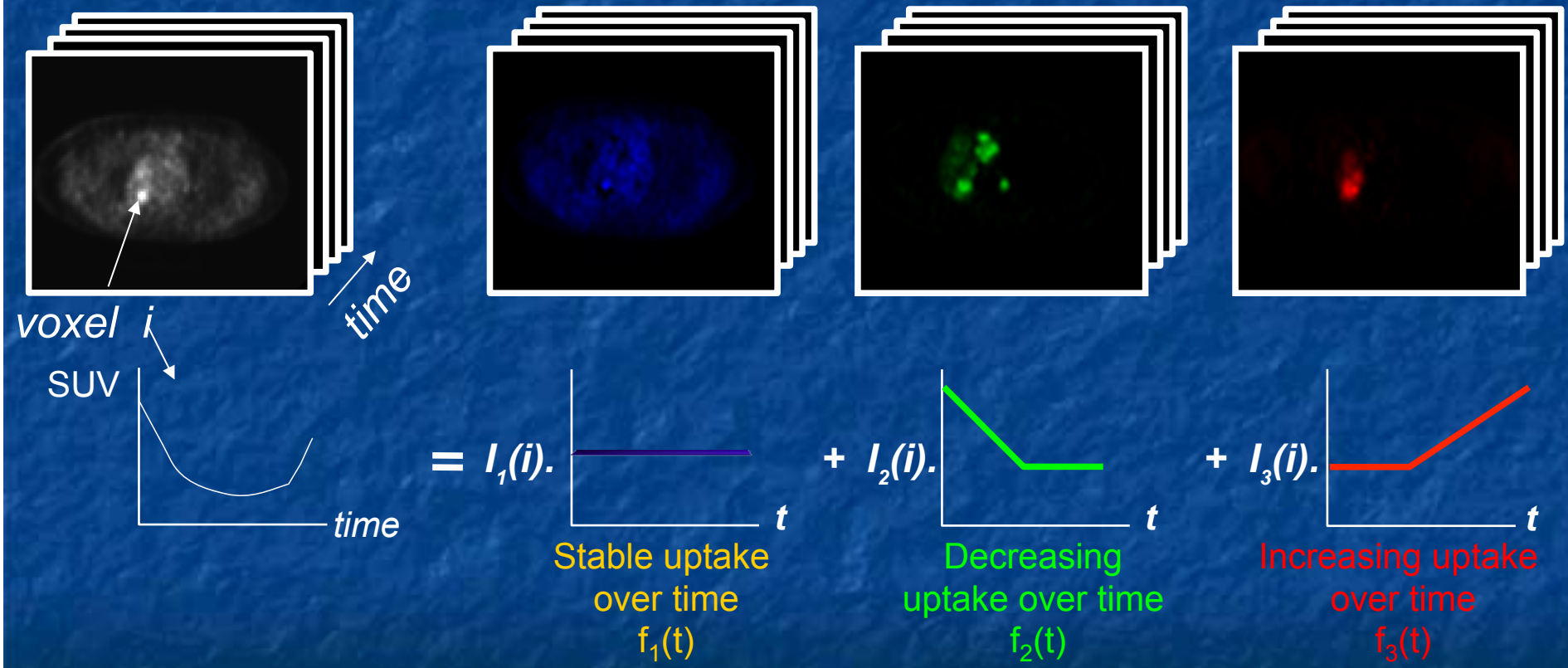

Use of the transformation identified based on the CT to register the PET scans



# Model : a factor analysis model

$$SUV(i,t) = \sum_{k=1}^{K} I_k(i).f_k(t) + \varepsilon_k(t)$$

- SUV units



# Solving the model

$$SUV(i,t) = \sum_{k=1}^{K} I_k(i).f_k(t) + \varepsilon_k(t)$$

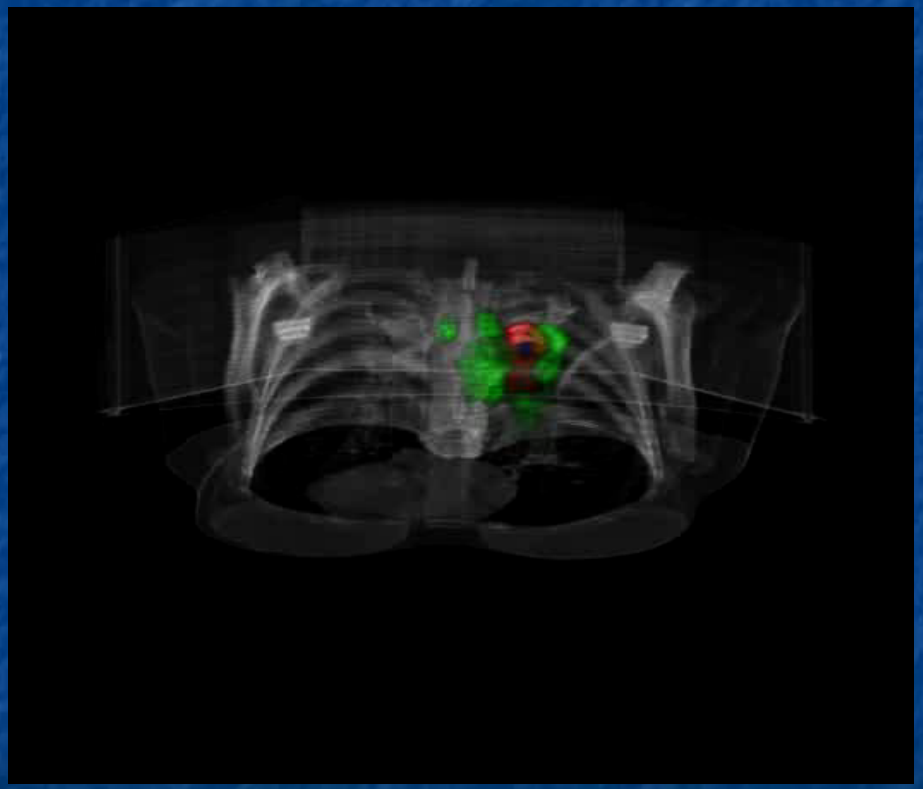
Priors :

- Non-negative $I_k(i)$ coefficients
- Non-negative $f_k(t)$ values
- In each voxel, the variance of the voxel value is roughly proportional to the mean

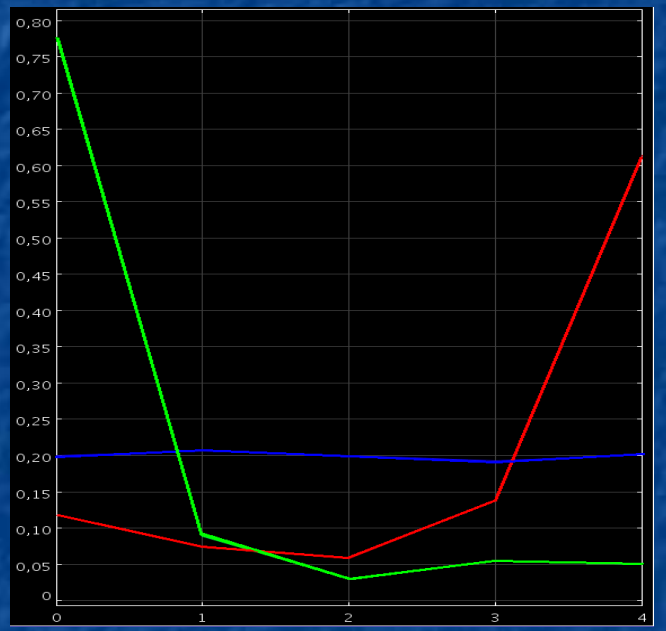
Iterative identification of $I_k(i)$ et $f_k(t)$ (Buvat et al Phys Med Biol 1998) using a Correspondence Analysis followed by an oblique rotation of the orthogonal eigenvectors

# Sample results

Lung cancer patient with 5 PET/CT scans



Normalized SUV



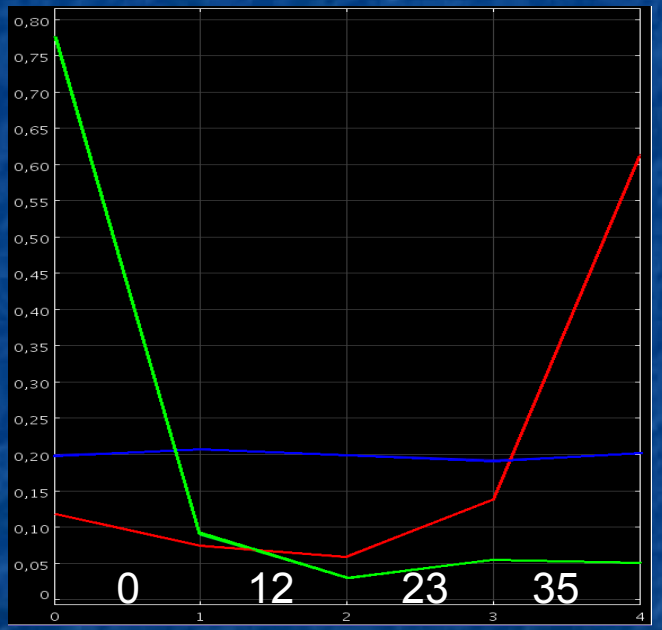

0 12 23 35 46

weeks

# Why is such an approach useful?

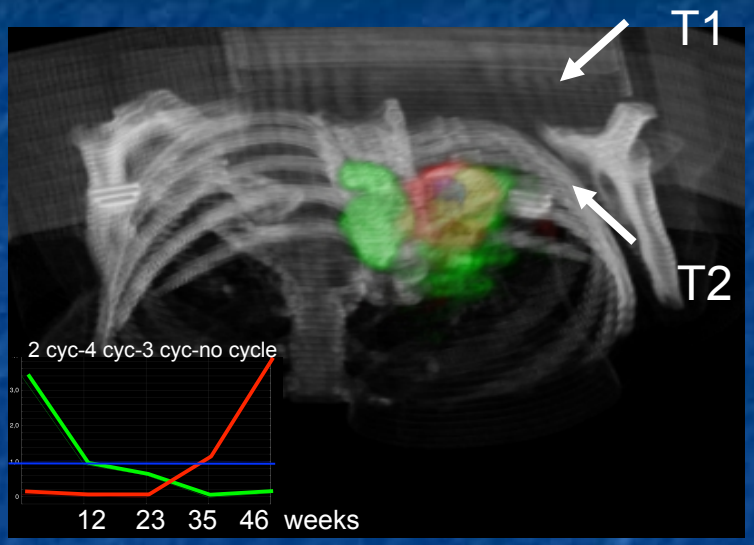
Heterogeneous tumor responses can be easily identified

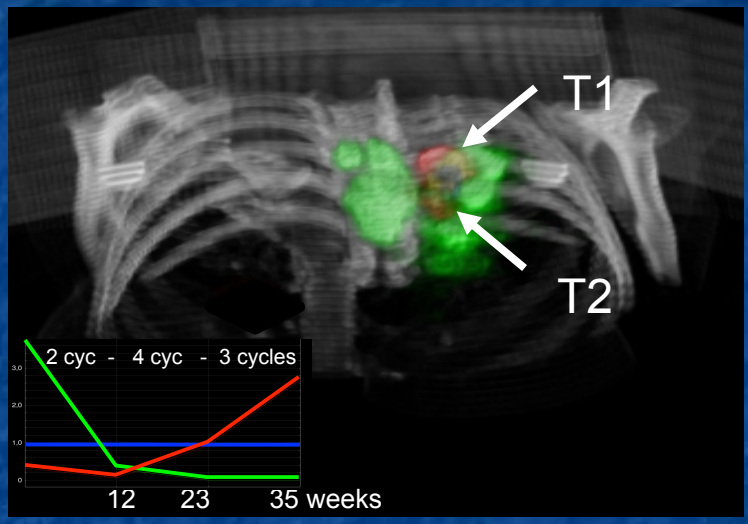
Normalized SUV

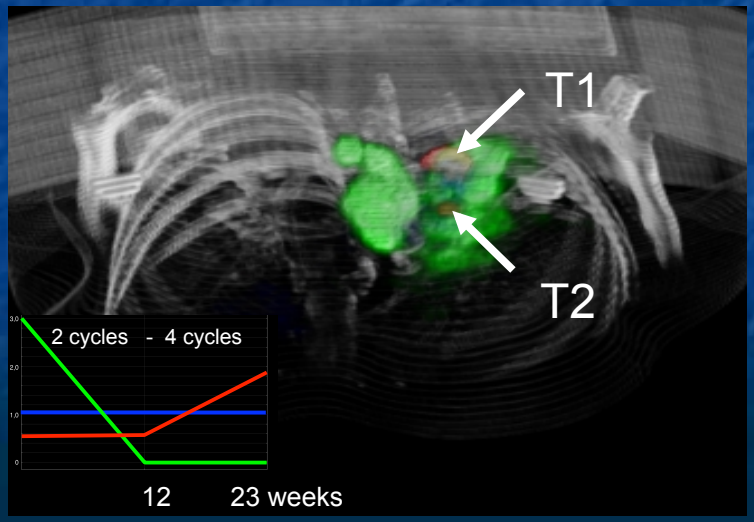


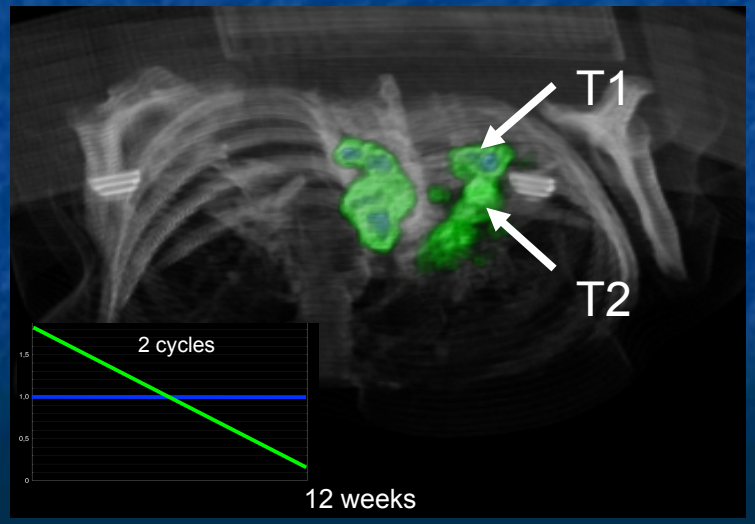

weeks

# Sample results: early detection of tumor recurrence (1)



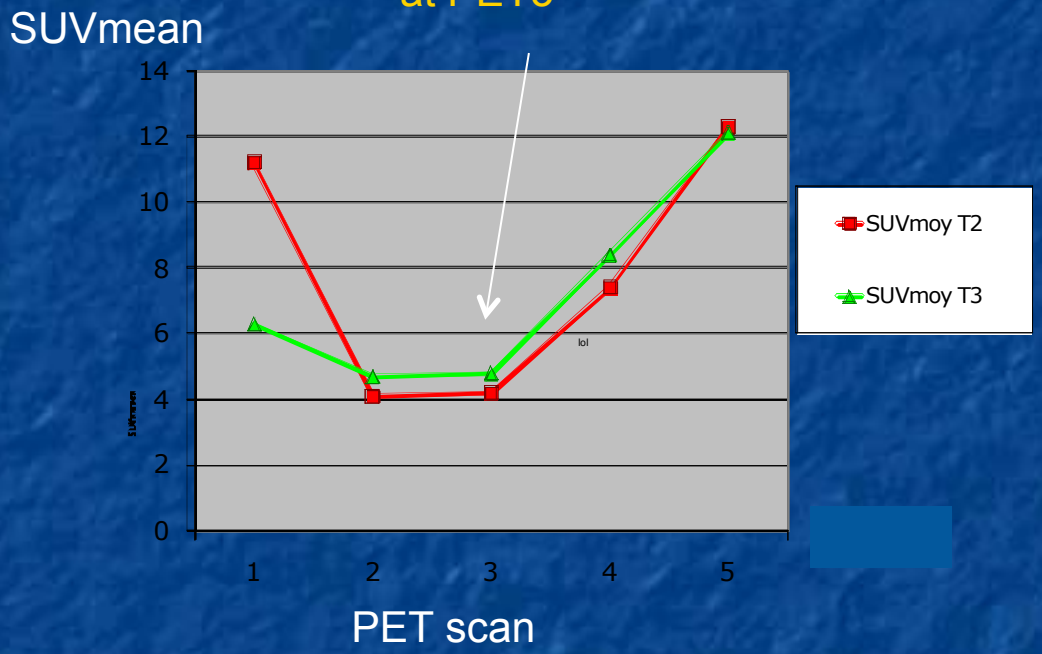



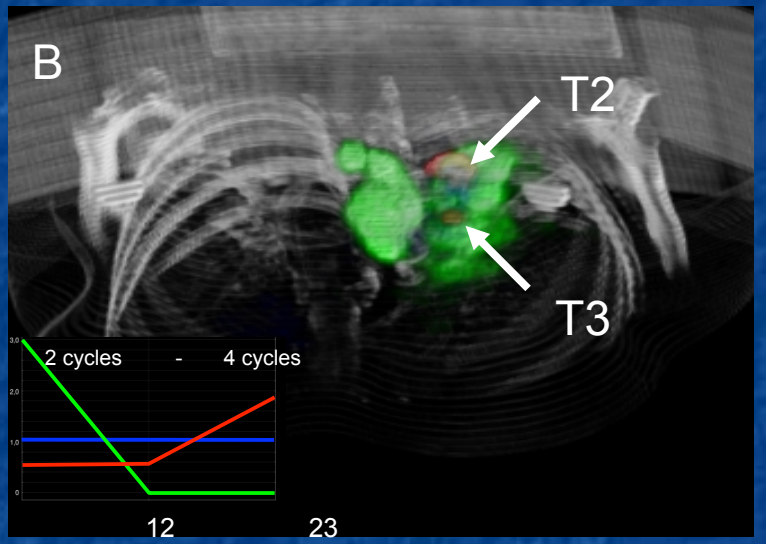



# Sample results: early detection of tumor recurrence (2)

EORTC : no tumor recurrence detected at PET3




PI : tumor recurrence detected at PET3

# Discussion / conclusion

- No need to precisely delineate the tumors

- Makes it possible to detect small changes in metabolic activity

- Summarizes changes between two or more scans in a single image

- Shows heterogeneous tumor response within a tumor or between tumors

# Thanks to

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