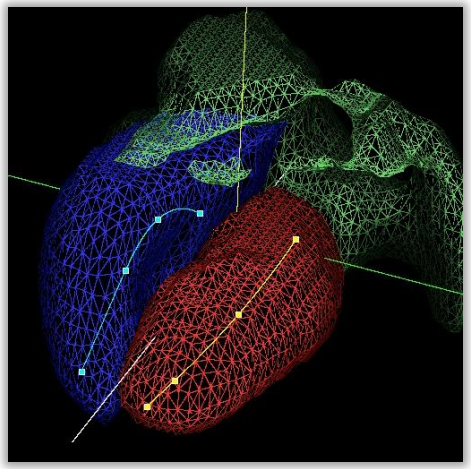
MASTER PhyMed

GMPH308 - Physique de l'imagerie médicale

ANALYSE d'IMAGES MEDICALES

Quelques solutions logicielles



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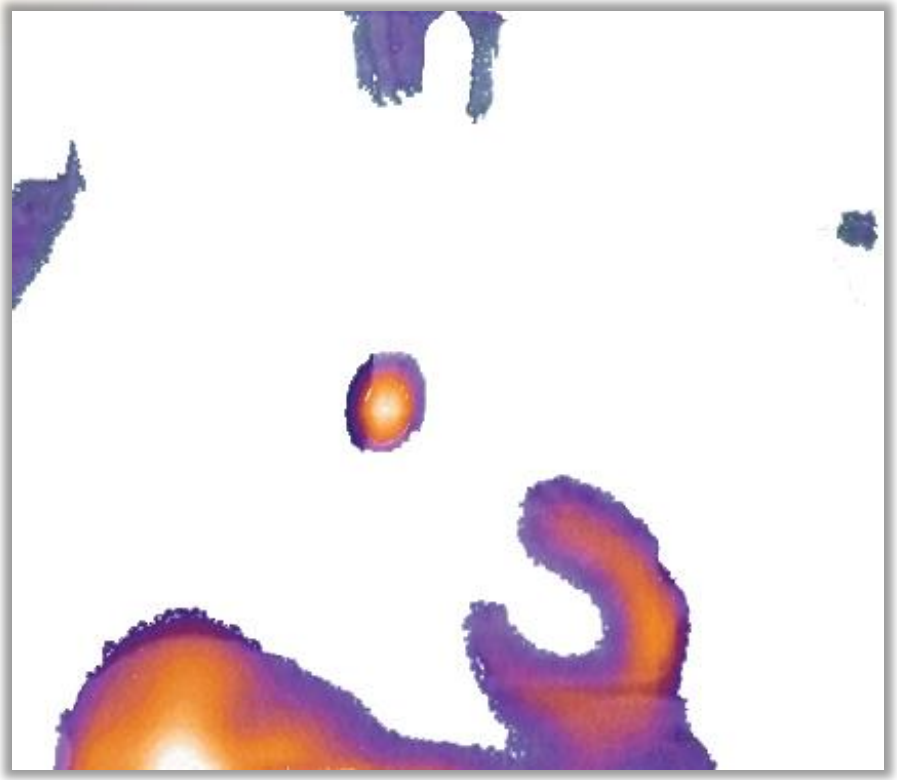
http://scinti.etud.univ-montp1.fr

Recalage d'images multimodales

- Localisation anatomique des anomalies fonctionnelles



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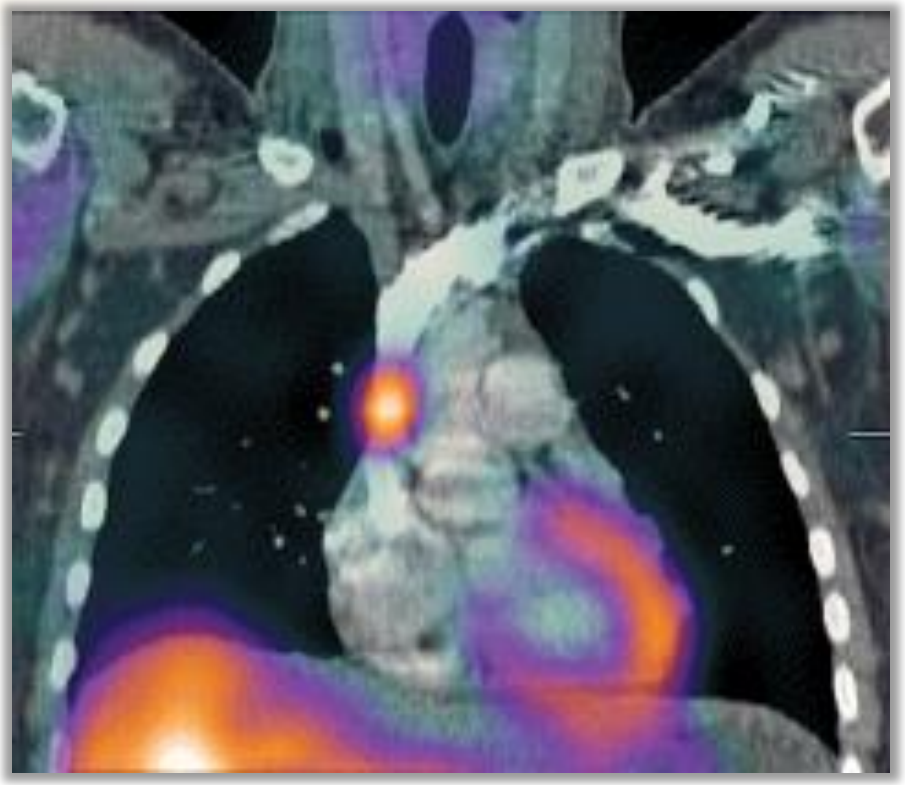
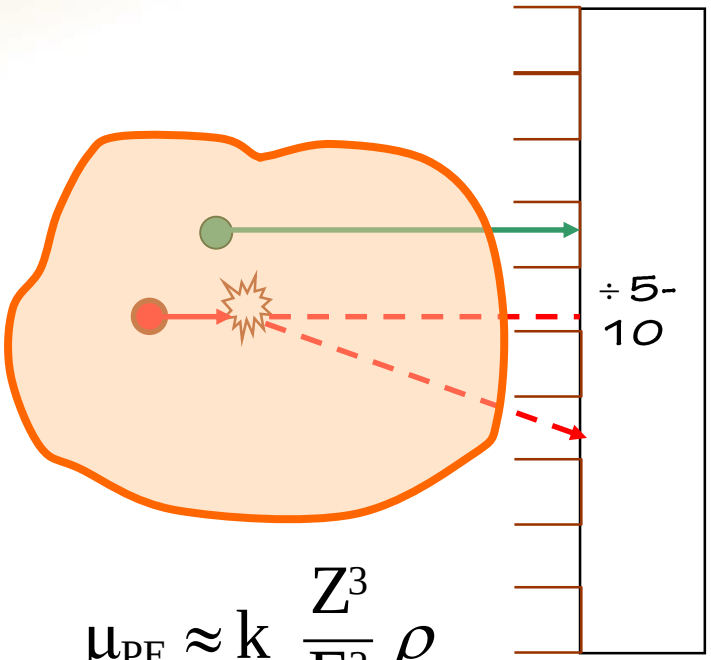


Recalage d'images multimodales

- Localisation anatomique des anomalies fonctionnelles
- Correction d'atténuation

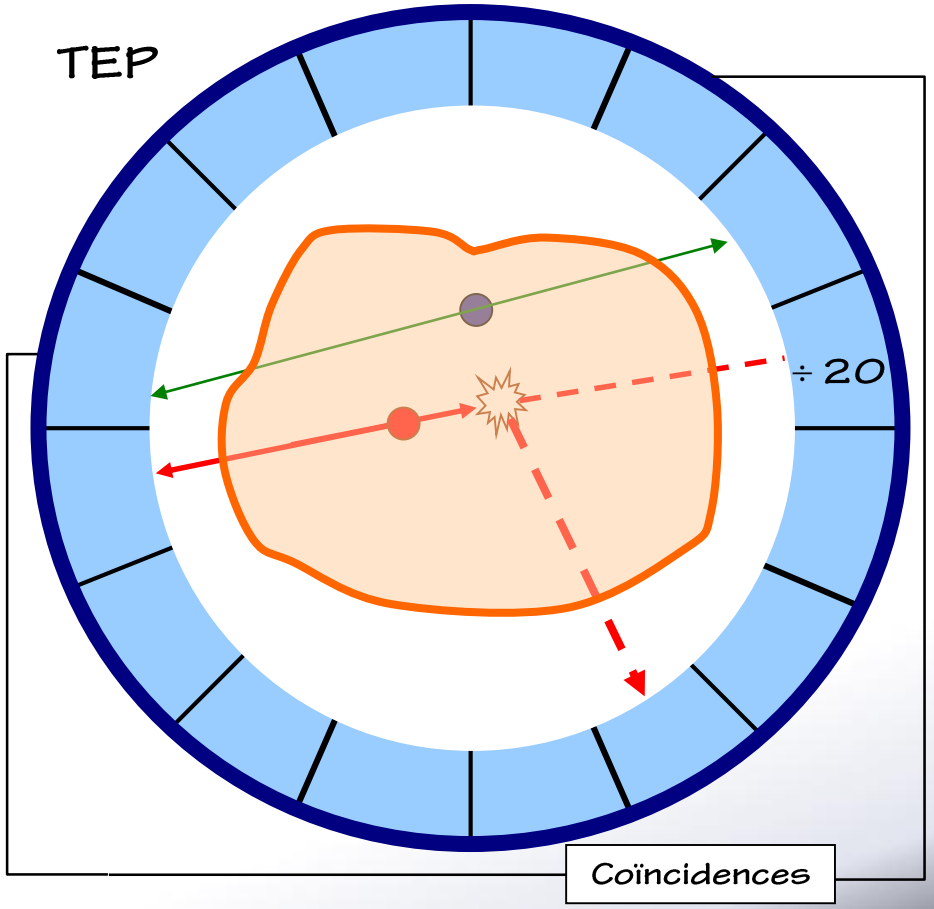
TEMP



$$\mu_{PE} \approx k \frac{Z^3}{E^3} \rho$$

$$\mu_C \approx k' \rho$$

TEP



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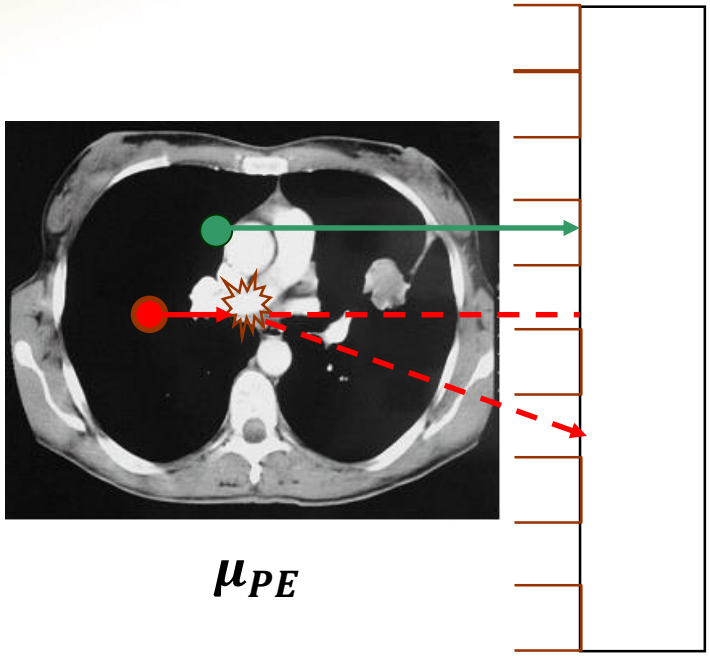
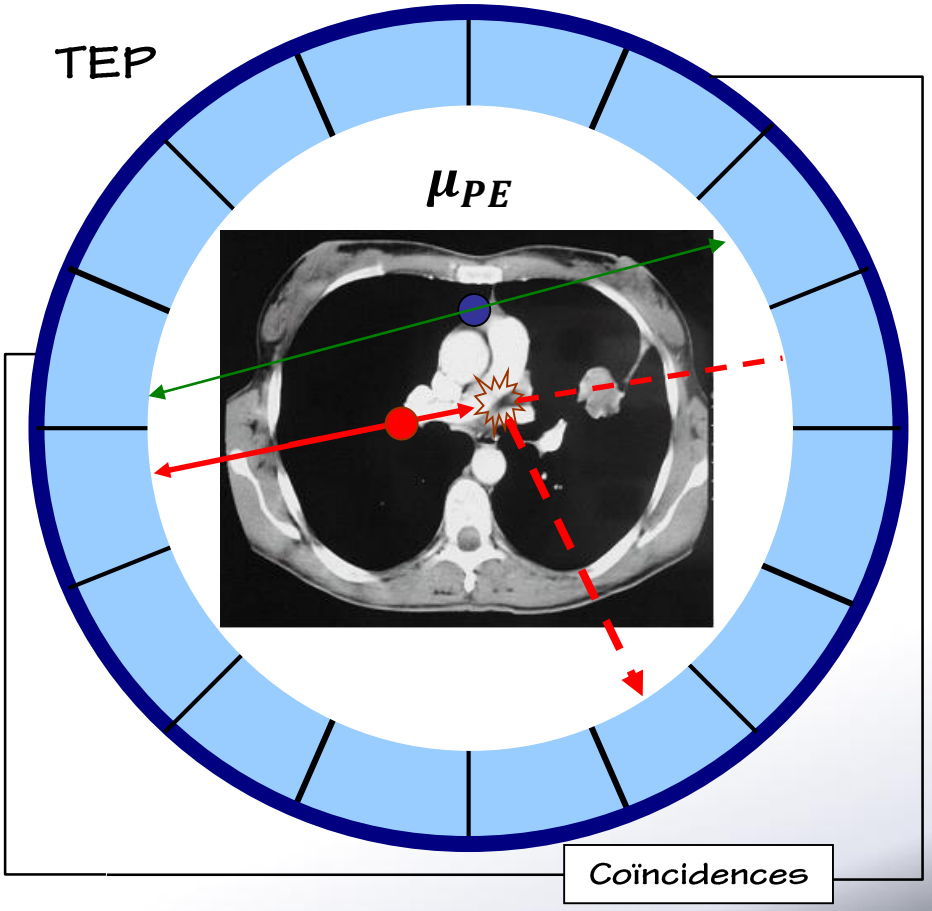
TEMP



TEP



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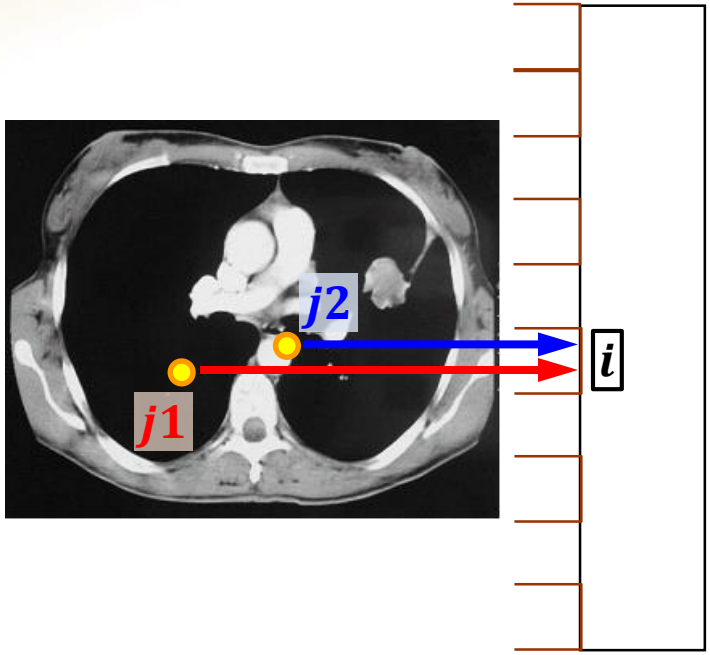


$$p = \mathbf{R}f$$

$$\mathbf{R}_{i,j1} = \wp(j1 \rightarrow i) = \lambda\, e^{-\int \mu\, dx}$$

$$\neq$$

$$\mathbf{R}_{i,j2} = \wp(j2 \rightarrow i) = \lambda\, e^{-\int \mu\, dx}$$

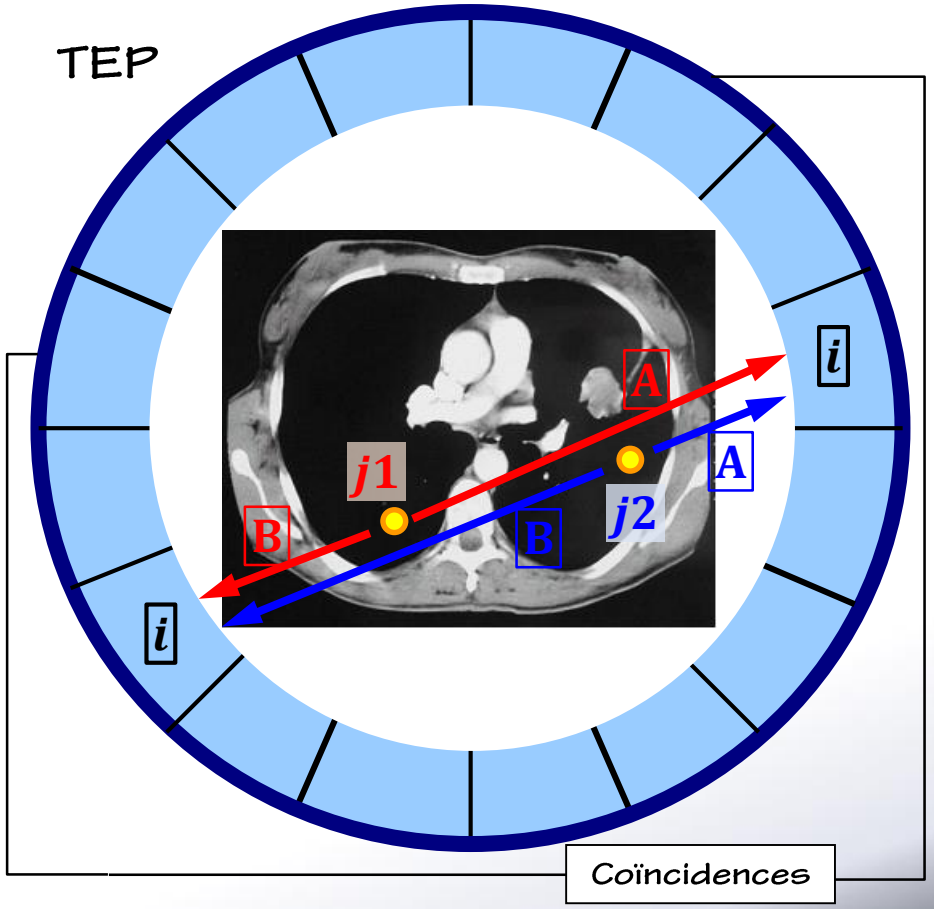
Recalage d'images multimodales

- Localisation anatomique des anomalies fonctionnelles
- Correction d'atténuation

$$p = \mathbf{R}f$$

$$\mathbf{R}_{i,j1} = \wp(j1 \rightarrow i) = \lambda \left[e^{-\int_A \mu\, dx} e^{-\int_B \mu\, dx} \right]$$

$$\mathbf{R}_{i,j2} = \wp(j2 \rightarrow i) = \lambda \left[e^{-\int_A \mu\, dx} e^{-\int_B \mu\, dx} \right]$$



Recalage d'images multimodales

- Localisation anatomique des anomalies fonctionnelles
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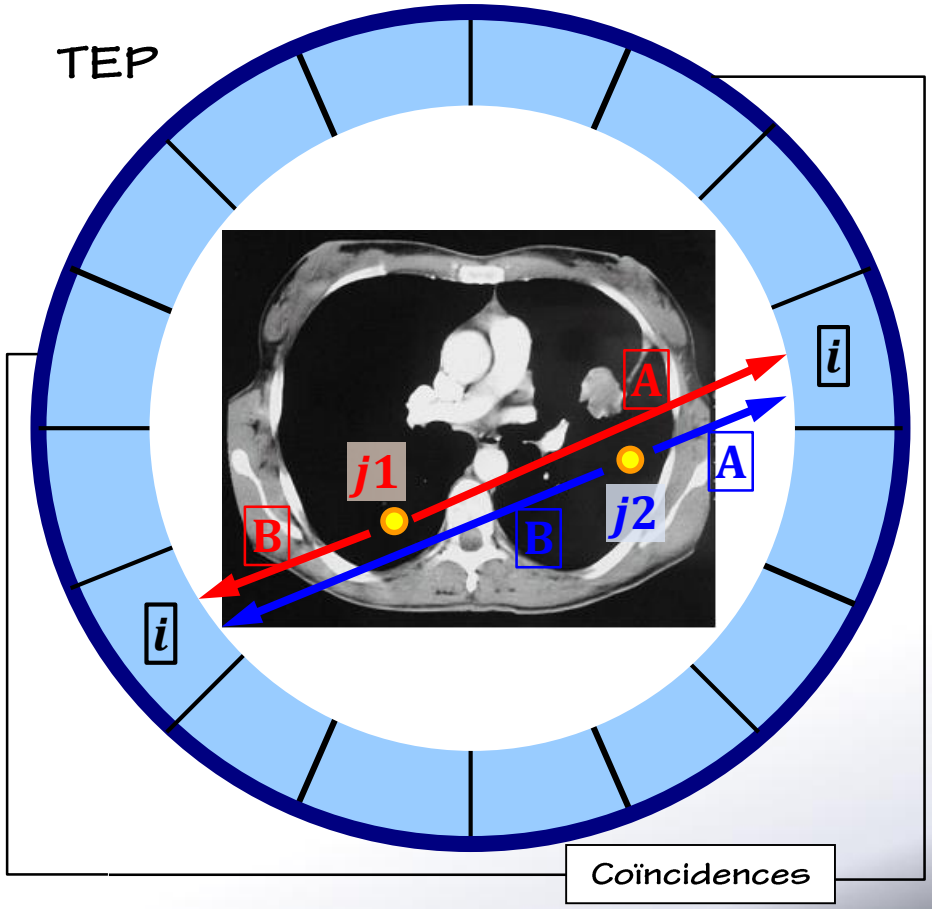
$$p = \mathrm{R}f$$

$$\mathrm{R}_{i,j1} = \wp(j1 \rightarrow i) = \lambda \left[e^{-\int_A \mu\, dx} e^{-\int_B \mu\, dx} \right]$$

$$= \lambda\, e^{-\int_{A+B} \mu\, dx} = \lambda\, \gamma_i$$

$$\mathrm{R}_{i,j2} = \wp(j2 \rightarrow i) = \lambda \left[e^{-\int_A \mu\, dx} e^{-\int_B \mu\, dx} \right]$$



Recalage d'images multimodales

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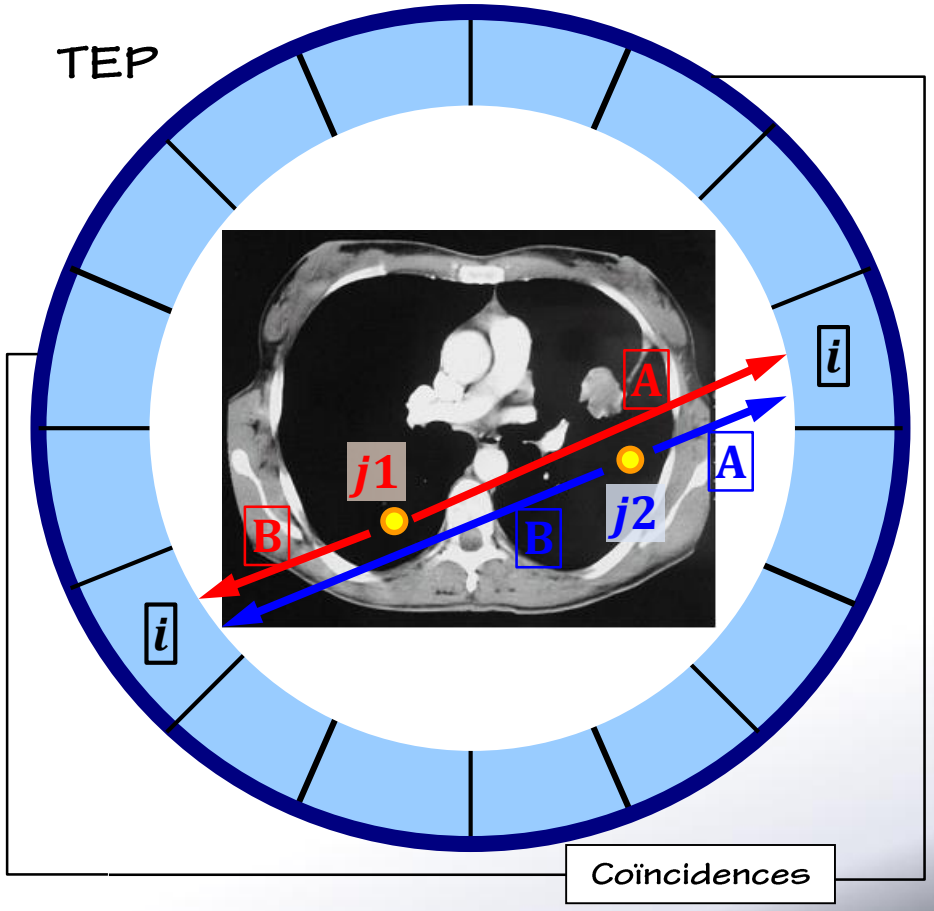
$$\mathrm{R}_{i,j2} = \wp(j2 \rightarrow i) = \lambda \left[e^{-\int_A \mu\, dx} e^{-\int_B \mu\, dx} \right]$$

$$\bar{\bar{p}}_i = p_i / \gamma_i$$

$$\bar{\bar{p}} = \mathrm{R}f$$



Recalage d'images multimodales

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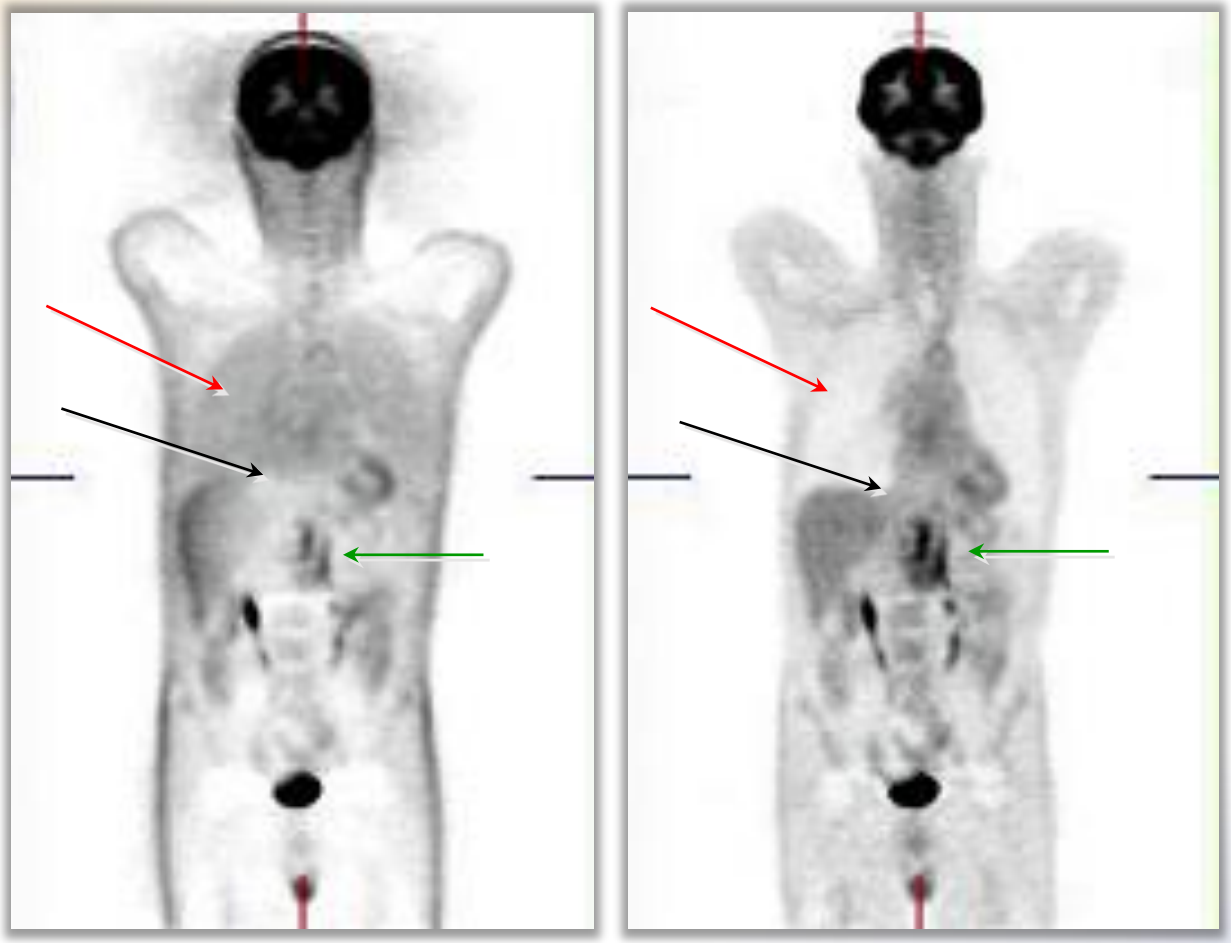
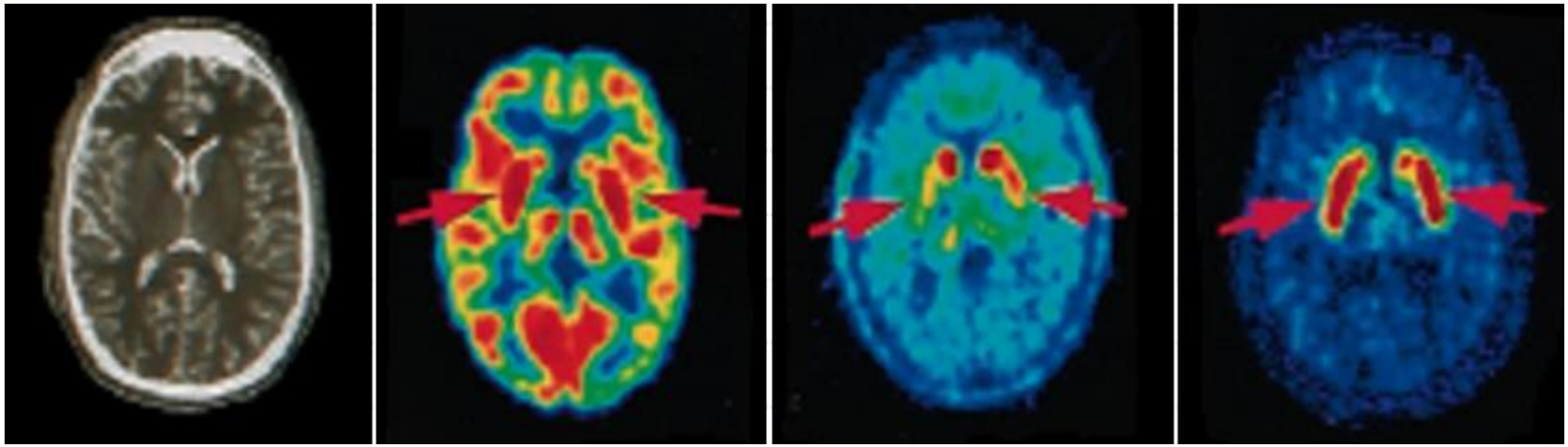


Non corrigé

Corrigé

Recalage d'images multimodales

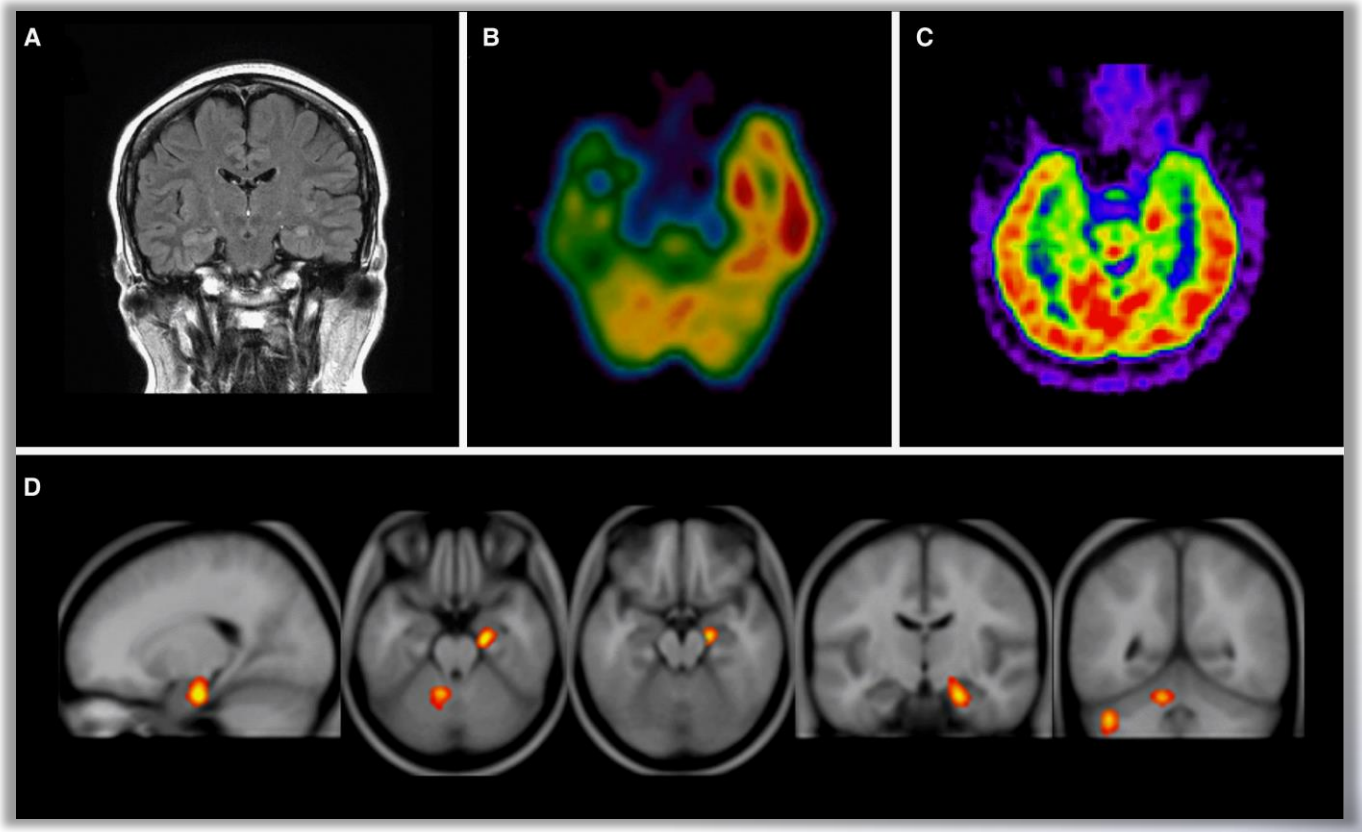
- Localisation anatomique des anomalies fonctionnelles
- Correction d'atténuation
- **Interprétation multimodale**



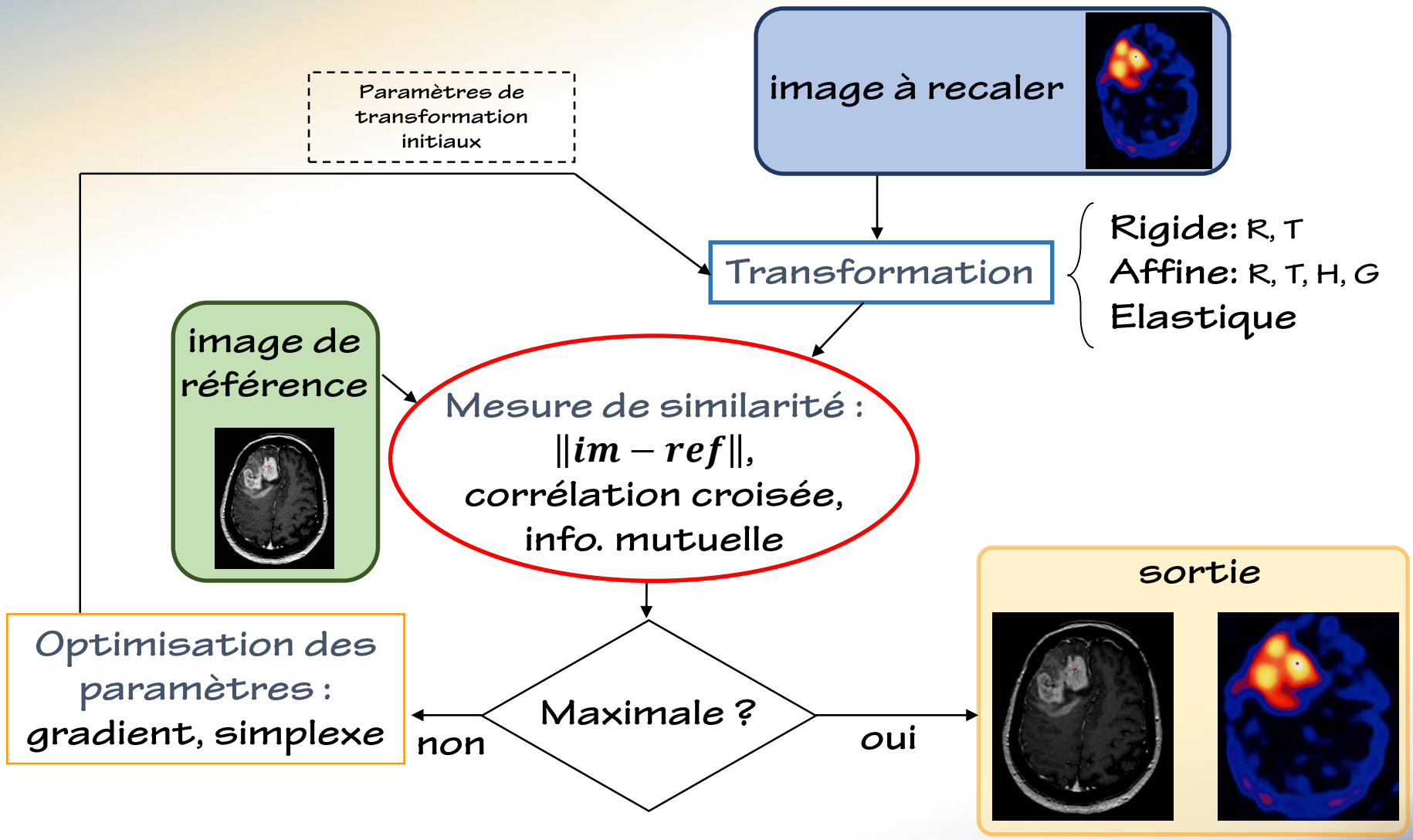
IRM | ^{18}F-DG | ^{18}F-DOPA | ^{18}F-éthyl-spipérone

Recalage d'images multimodales

- Localisation anatomique des anomalies fonctionnelles
- Correction d'atténuation
- Interprétation multimodale
- Cartographie statistiques (SPM)



Recalage d'images multimodales

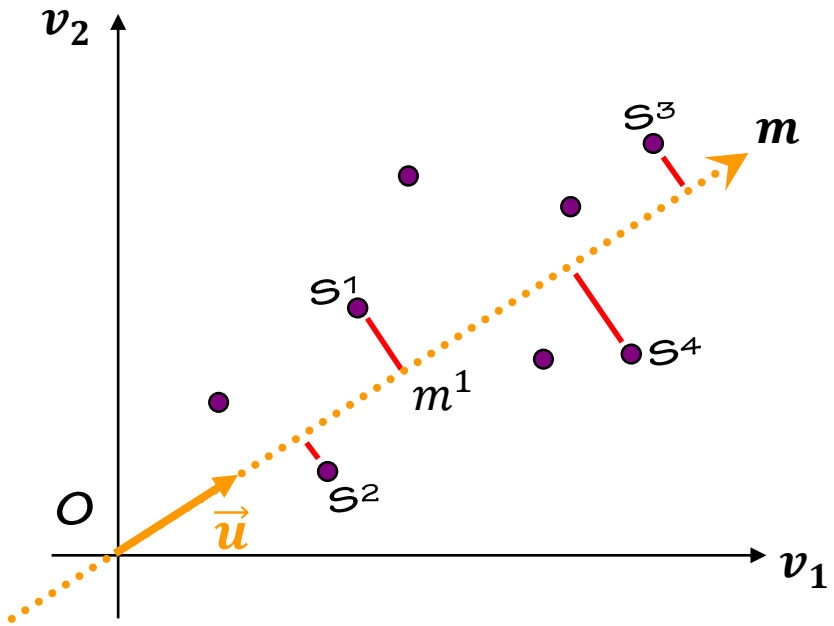


Analyse factorielle

Analyse de 2 variables v_k (ex: taille et poids) sur N sujets S^n

$$\mathbf{M} = \begin{bmatrix} v_1^1 & v_2^1 \\ v_1^2 & v_2^2 \\ v_1^3 & v_2^3 \\ v_1^4 & v_2^4 \end{bmatrix} \longrightarrow \text{sujet } S^2$$

variable v_1 : variable v_2



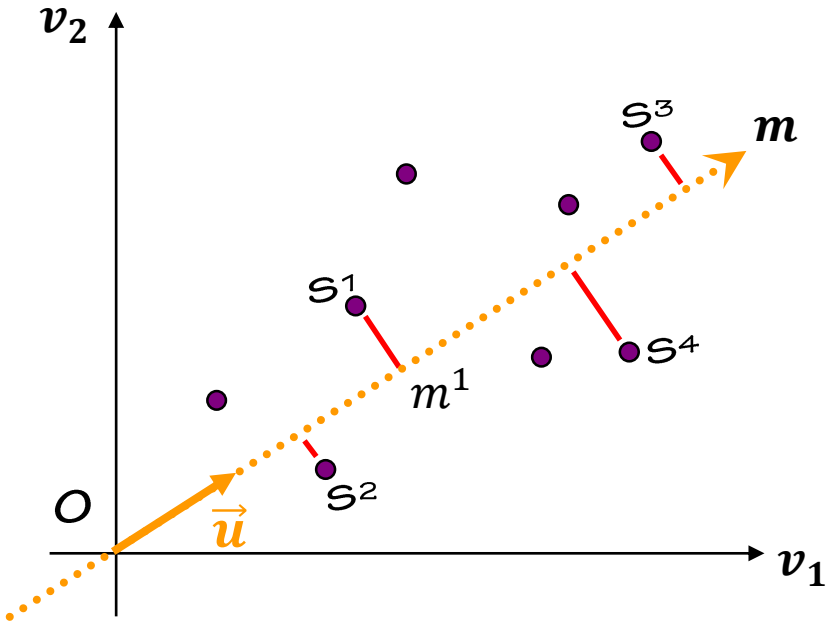
Idée : isoler les caractéristiques principales de chaque sujet S^n en ne le décrivant que par le point m^n (ex: « costaud » ou pas)

Analyse factorielle

Analyse de 2 variables v_k (ex: taille et poids) sur N sujets S^n

$$\boldsymbol{m} = \mathbf{M}\boldsymbol{u}$$

$$Var(\boldsymbol{m}) = \frac{1}{\mathrm{N}}\boldsymbol{m}^{\mathrm{T}}\boldsymbol{m} = \frac{1}{\mathrm{N}}\boldsymbol{u}^{\mathrm{T}}\mathbf{M}^{\mathrm{T}}\mathbf{M}\boldsymbol{u} = \boldsymbol{u}^{\mathrm{T}}\mathbf{C}\boldsymbol{u}$$



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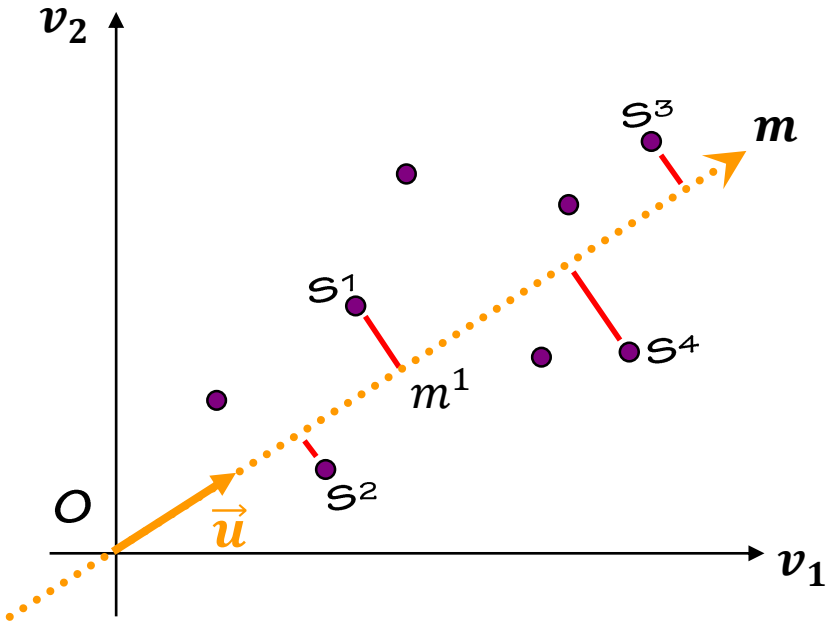
$$\boldsymbol{u} = \sum \alpha_n \boldsymbol{c}_n$$

$$Var(\boldsymbol{m}) = \sum \alpha_n^2 \, \boldsymbol{c}_n^{\mathrm{T}}\mathbf{C} \, \boldsymbol{c}_n$$

$$= \sum \alpha_n^2 \, \lambda_n \, \boldsymbol{c}_n^{\mathrm{T}}\boldsymbol{c}_n = \sum \alpha_n^2 \, \lambda_n$$



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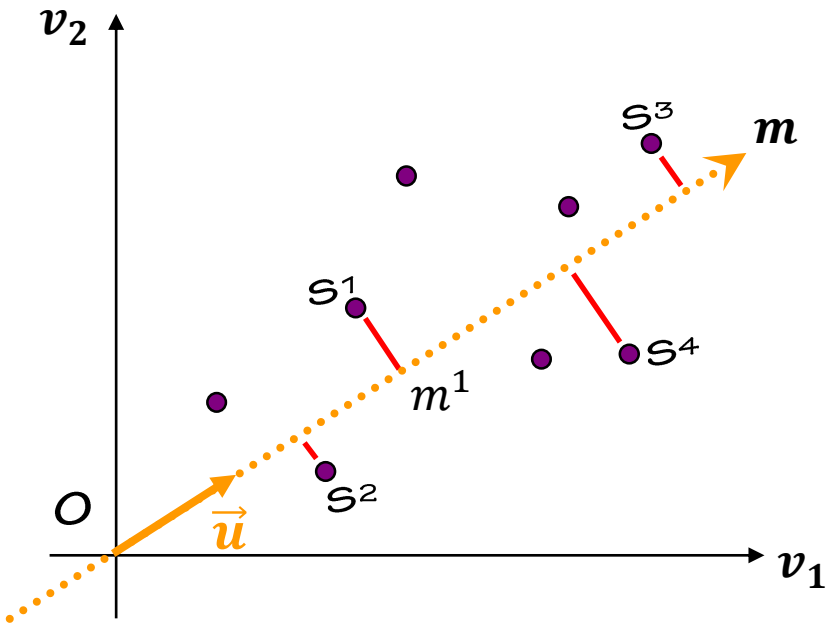
$$= \sum \alpha_n^2 \, \lambda_n \, \boldsymbol{c}_n^{\mathrm{T}}\boldsymbol{c}_n = \sum \alpha_n^2 \, \lambda_n$$

$$max\,\{Var(\boldsymbol{m})\} = \lambda_1 \;:\; \boldsymbol{u} = \boldsymbol{c}_1$$



$\boldsymbol{u}$ est le vecteur propre de C de valeur propre maximale

Analyse factorielle

Analyse de 2 variables v_k (ex: taille et poids) sur N sujets S^n

$$\boldsymbol{m} = \mathbf{M}\boldsymbol{u}$$

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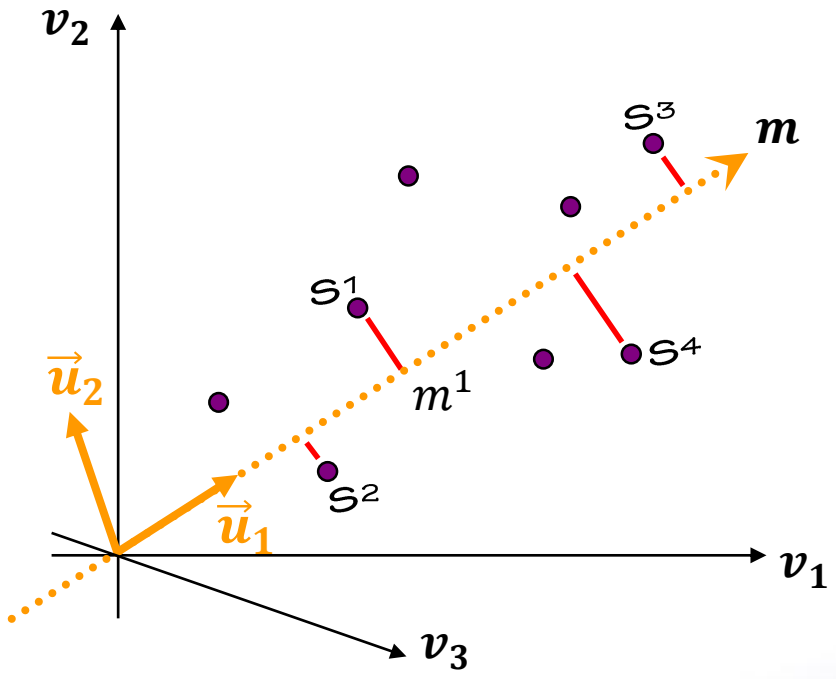
$$= \sum \alpha_n^2 \, \lambda_n \, \boldsymbol{c}_n^{\mathrm{T}}\boldsymbol{c}_n = \sum \alpha_n^2 \, \lambda_n$$

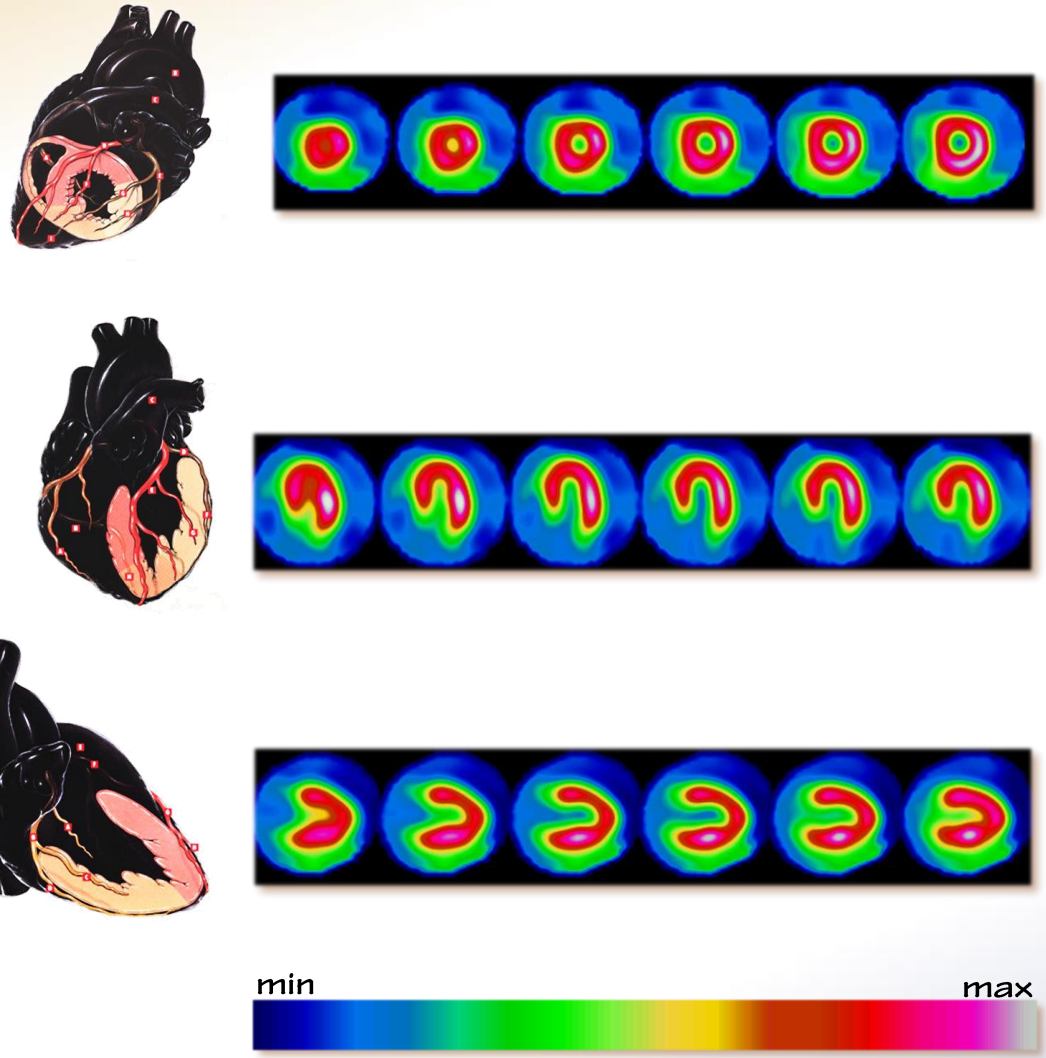


$max\,\{Var(\boldsymbol{m})\} = \lambda_1 + \lambda_2 + \ \ldots$
$\boldsymbol{u}_1 = \boldsymbol{c}_1\,;\boldsymbol{u}_2 = \boldsymbol{c}_2\,;\ldots$

Les $\boldsymbol{u}_n$ sont les vecteurs propres de $\mathbf{C}$ de valeurs propres maximales

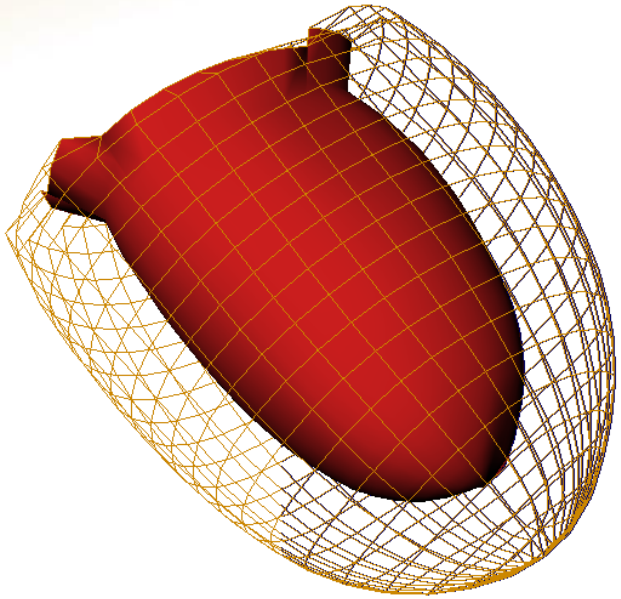
Analyse factorielle

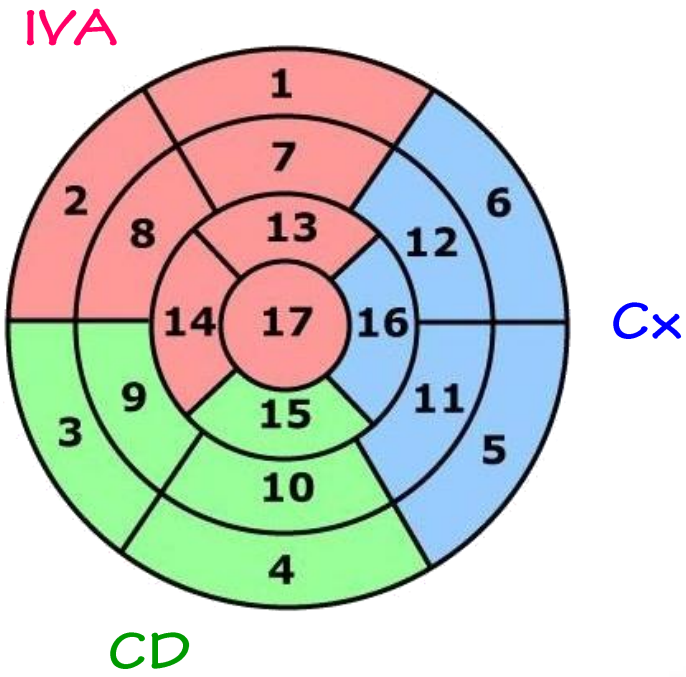
SPECT dynamique



Analyse factorielle

SPECT dynamique

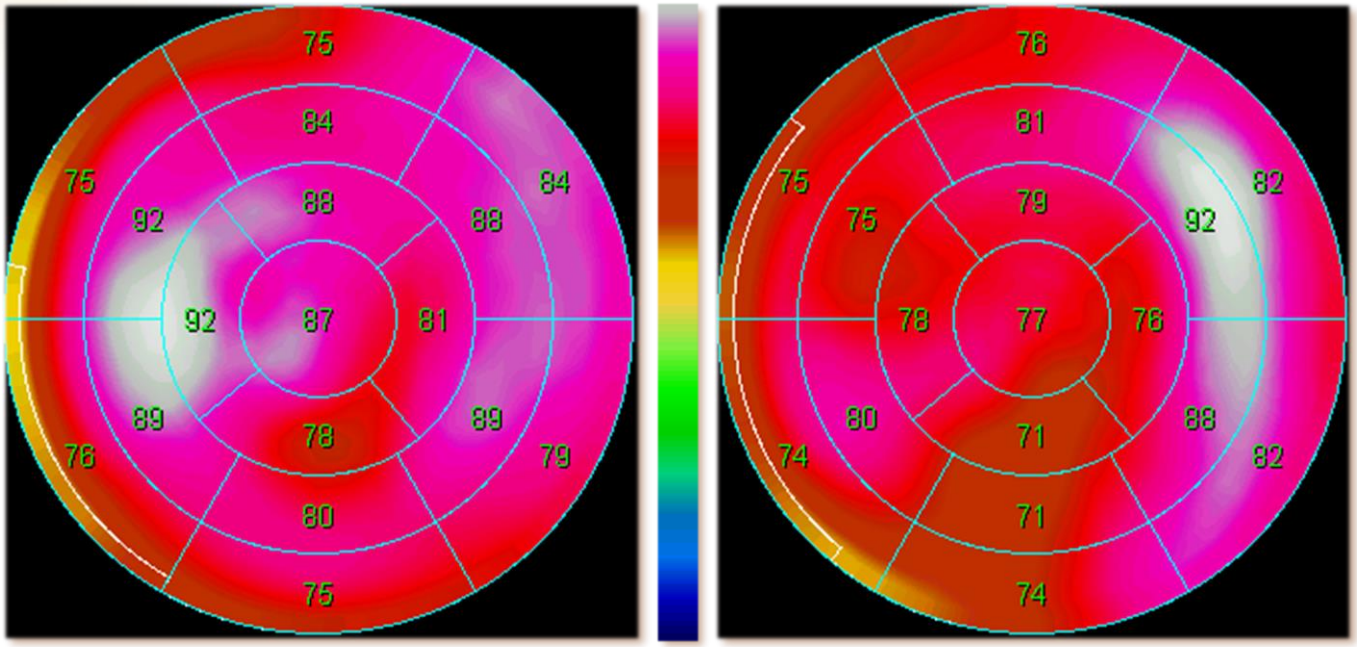




Analyse factorielle

SPECT dynamique

Effort



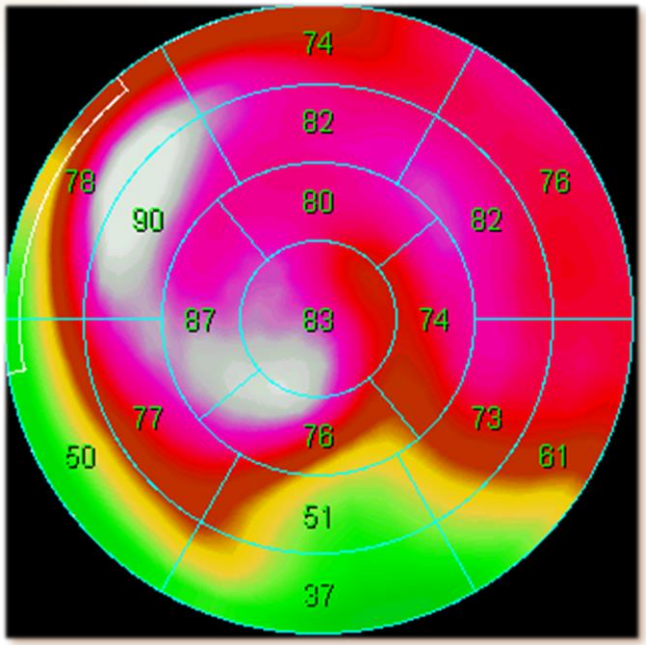
Repos

Scintigraphie normale

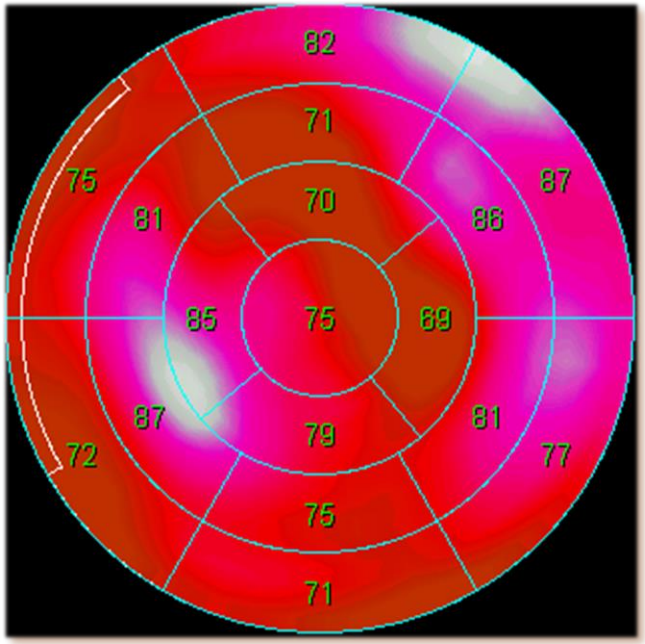
Analyse factorielle

SPECT dynamique

Effort



Repos



Ischémie myocardique

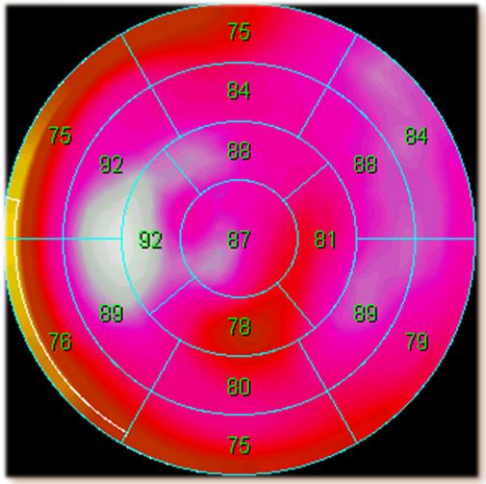
Analyse factorielle

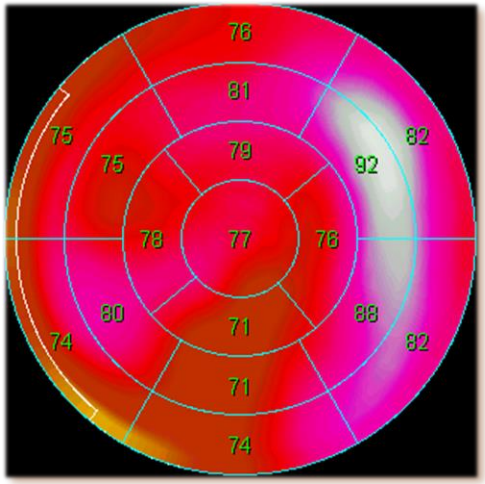
SPECT dynamique

Effort

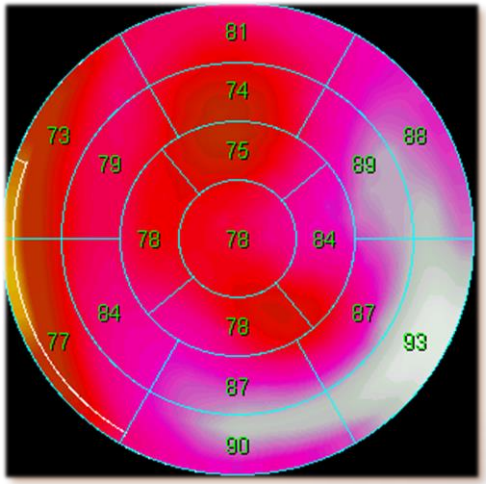
Repos

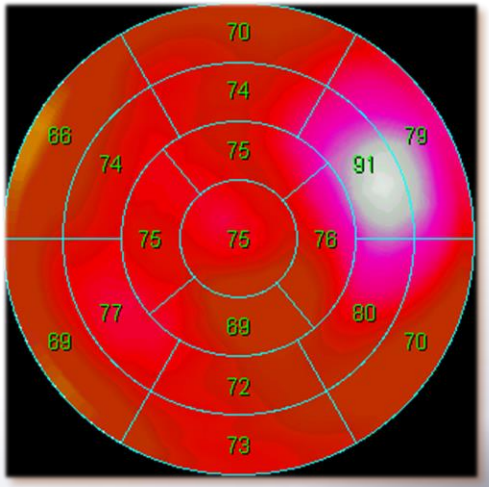
Scintigraphie normale





Pathologie
tri-tronculaire
« équilibrée »





Analyse factorielle

SPECT dynamique

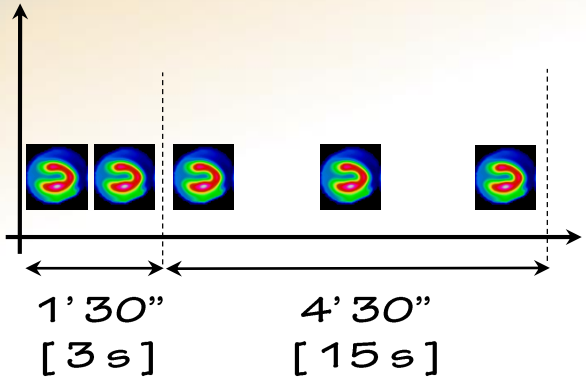
REPOS

MIBI
5 mCi

Analyse factorielle

SPECT dynamique

REPOS

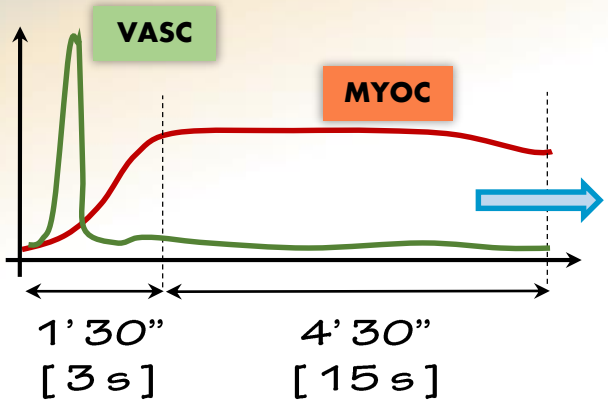


MIBI
5 mCi

Analyse factorielle

SPECT dynamique

REPOS



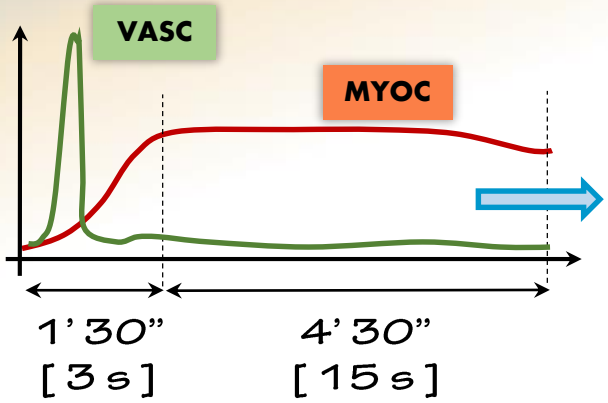
$K_1 \propto Q_{Repos}$

MIBI
5 mCi

Analyse factorielle

SPECT dynamique

REPOS

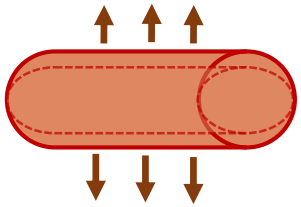


$K_1 \propto Q_{Repos}$

MIBI
5 mCi

STRESS

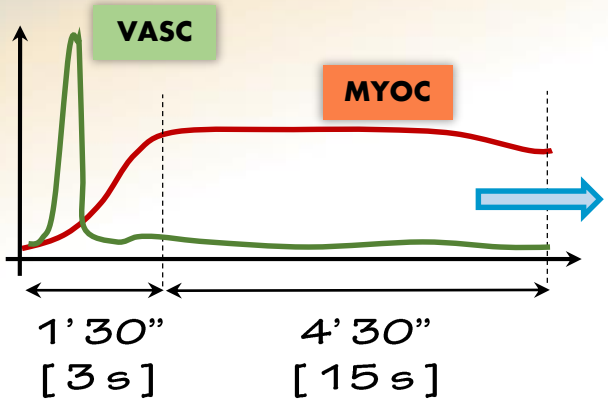
Dipyridamole



Analyse factorielle

SPECT dynamique

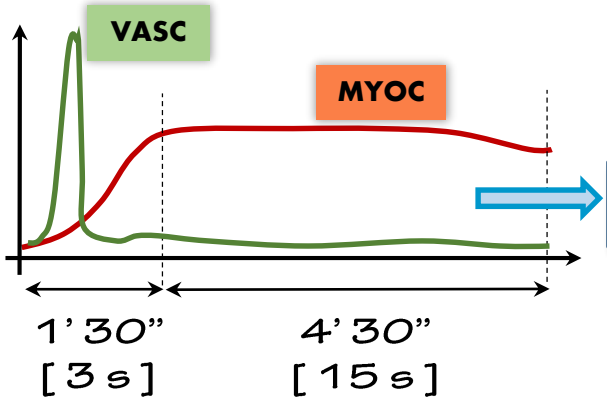
REPOS



$K_1 \propto Q_{Repos}$

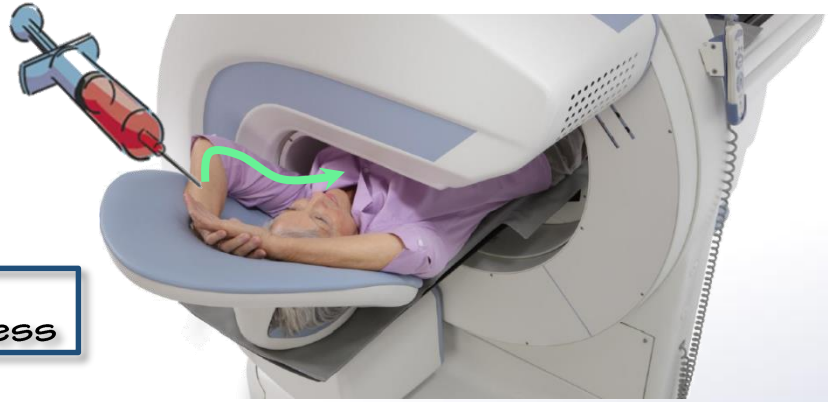
MIBI
5 mCi

STRESS



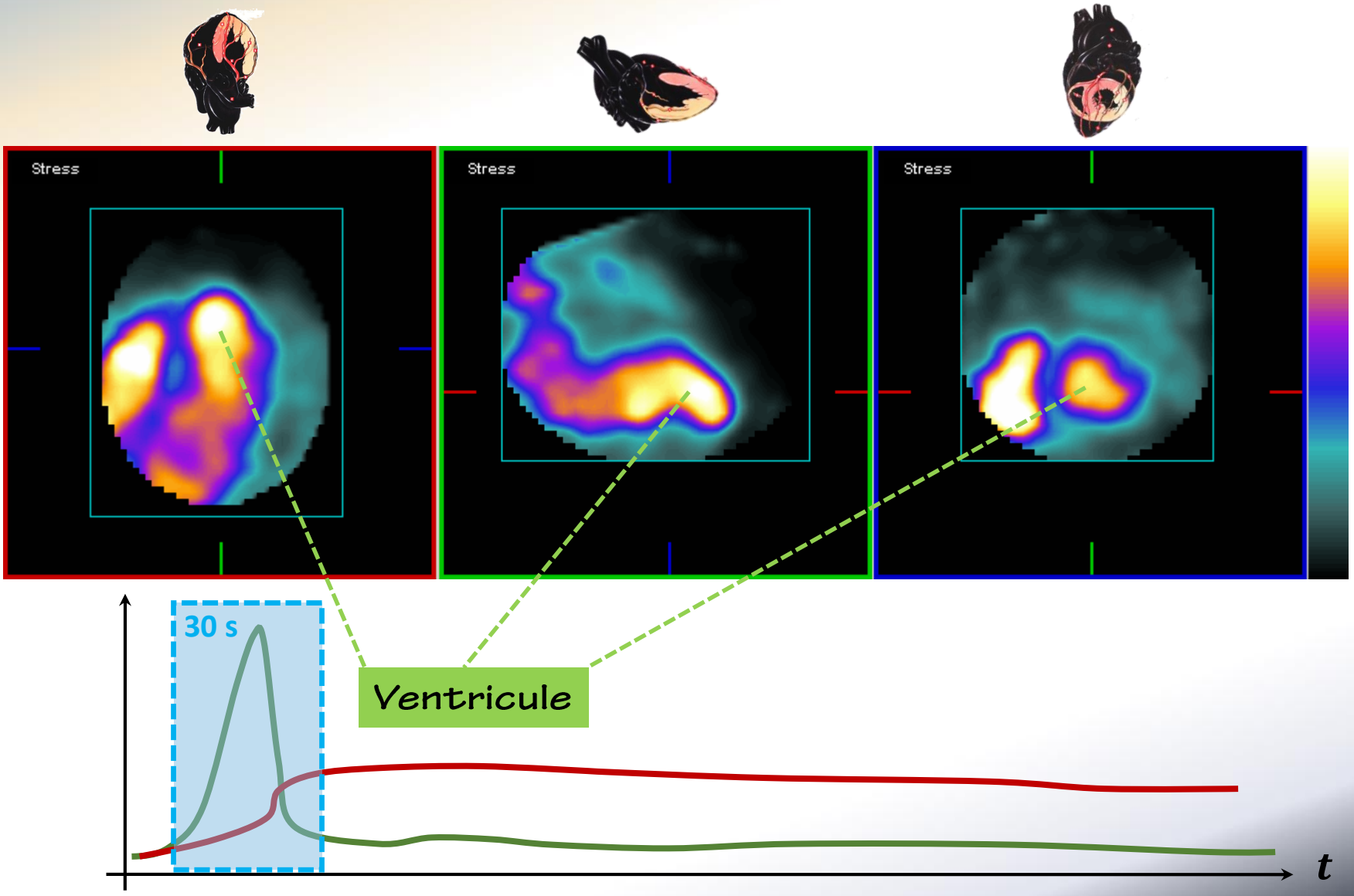
$K_1 \propto Q_{Stress}$

MIBI
20 mCi



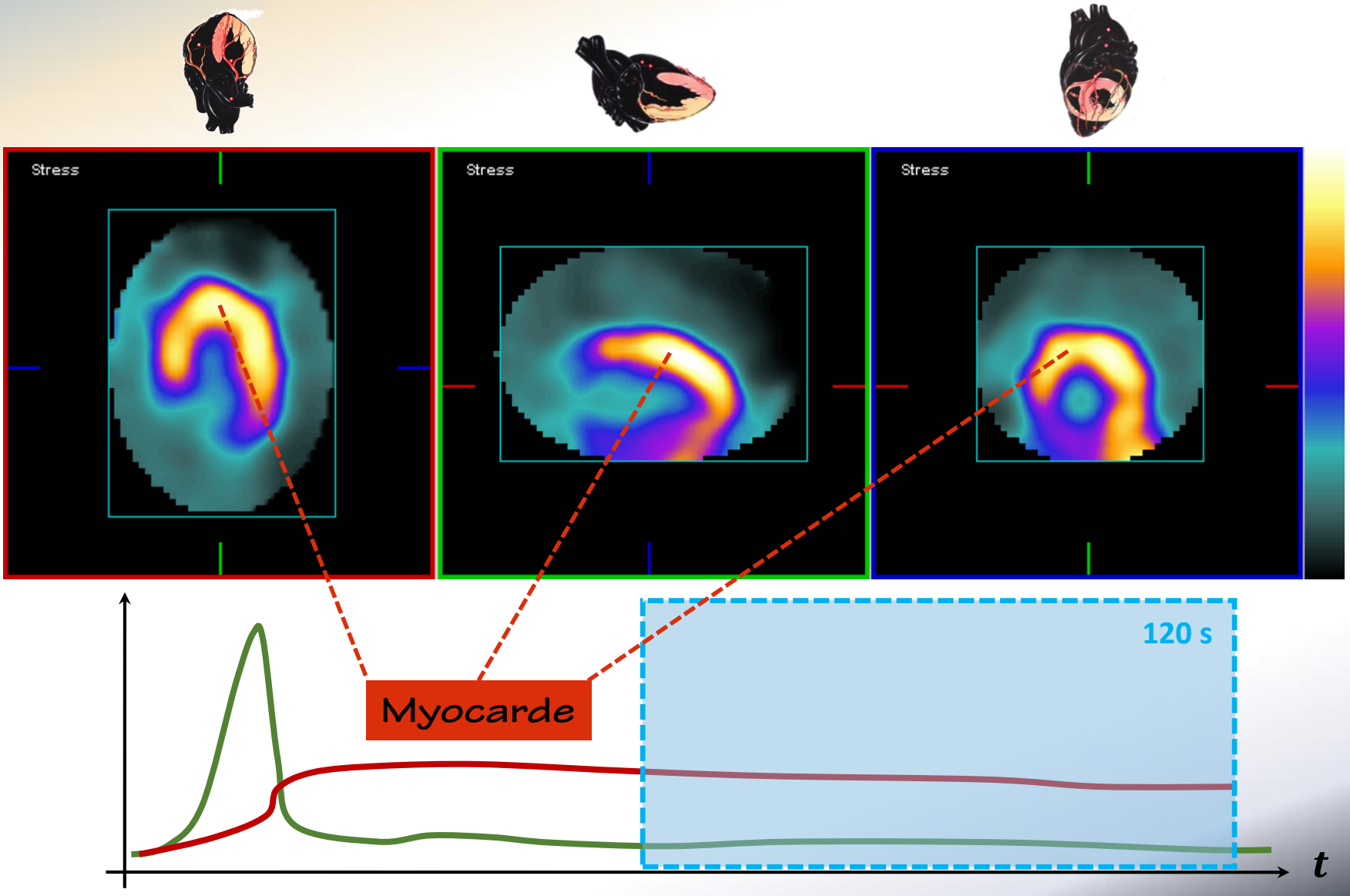
Analyse factorielle

SPECT dynamique

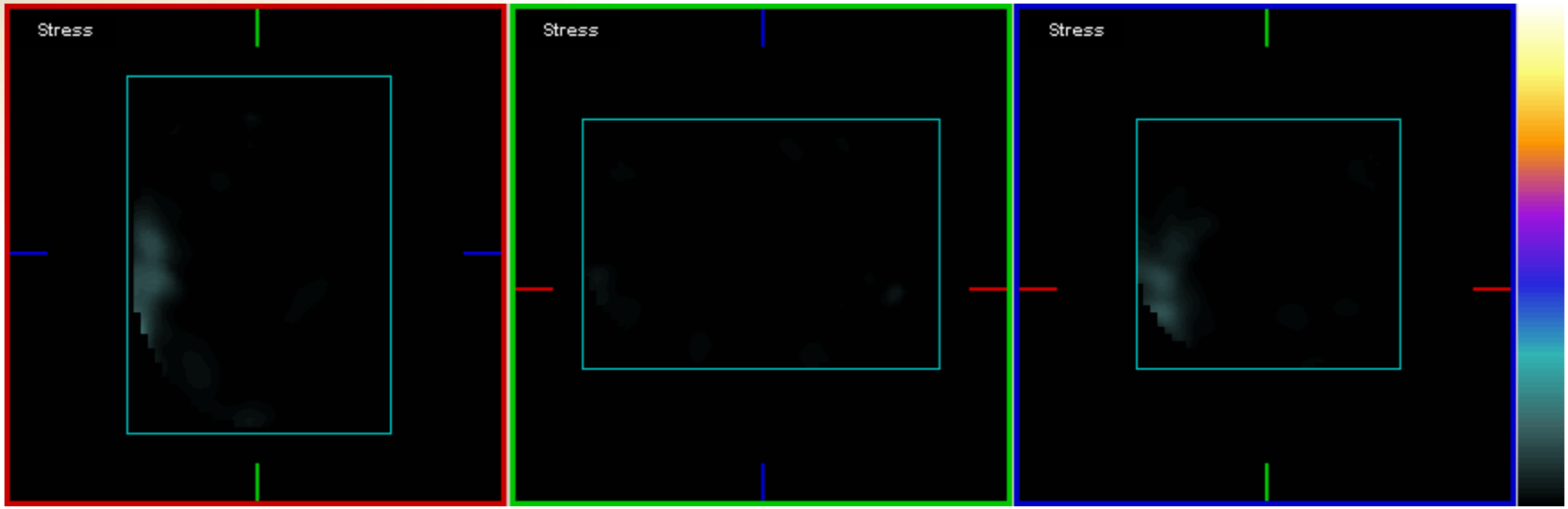


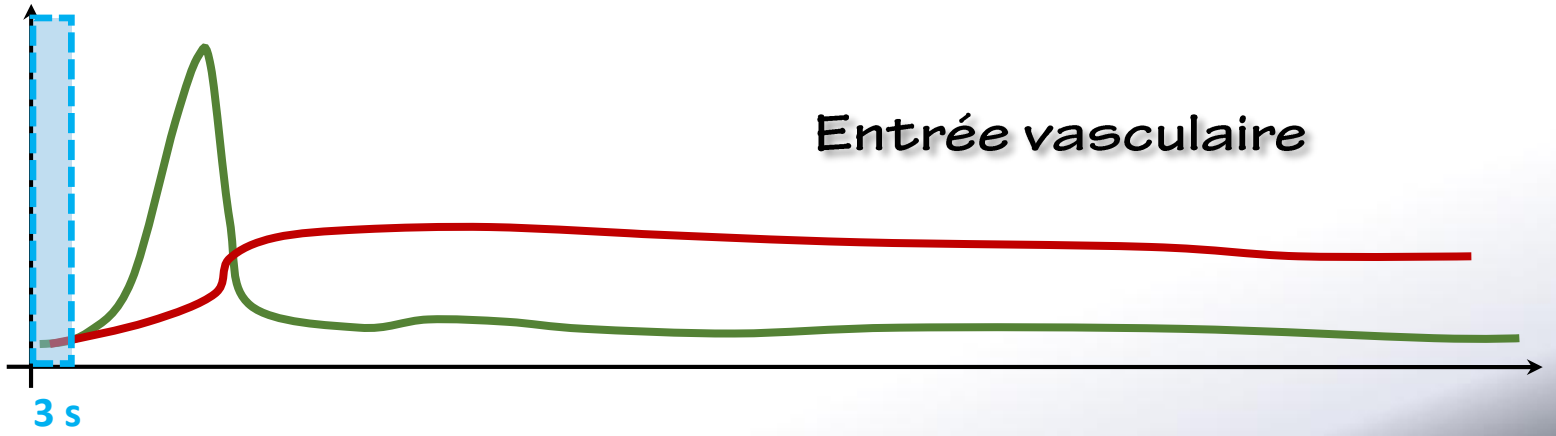
Analyse factorielle

SPECT dynamique

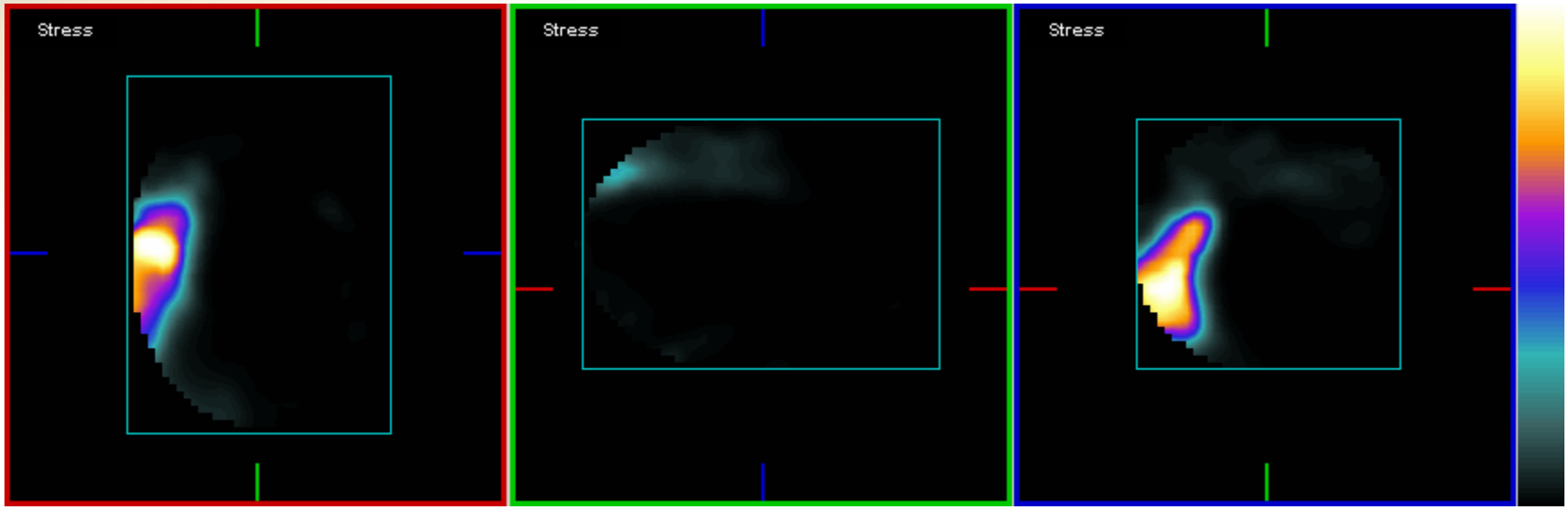


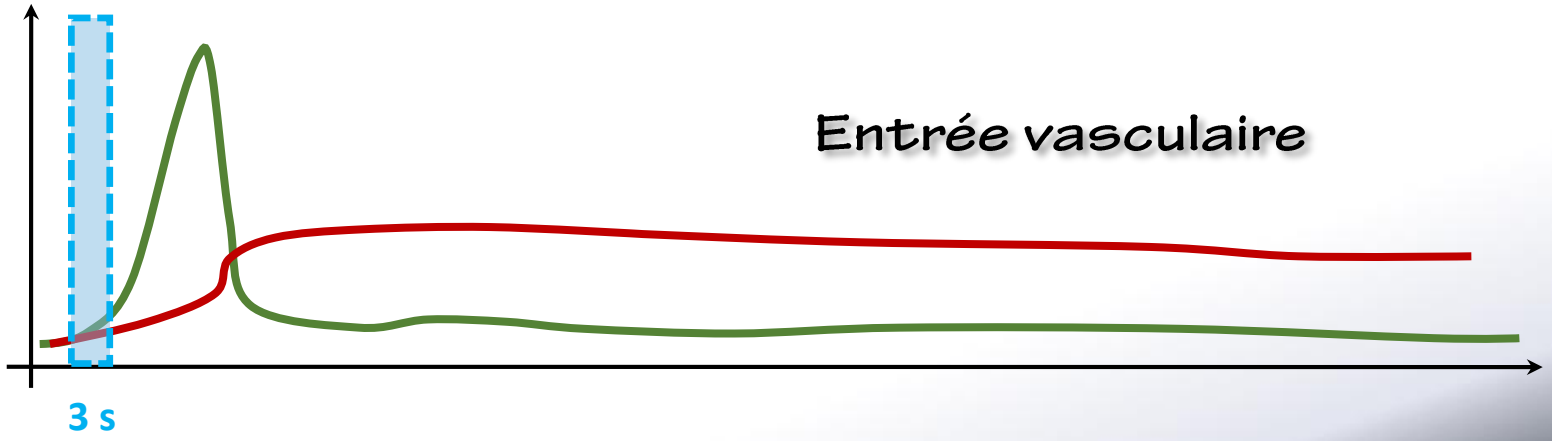
Analyse factorielle



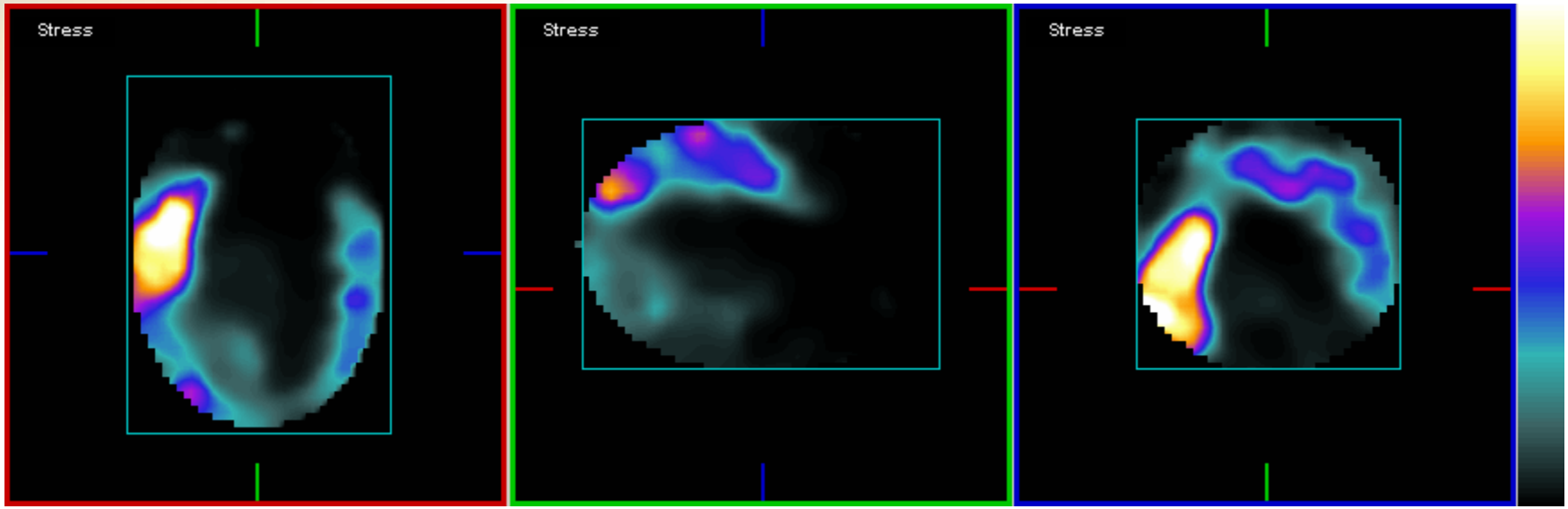


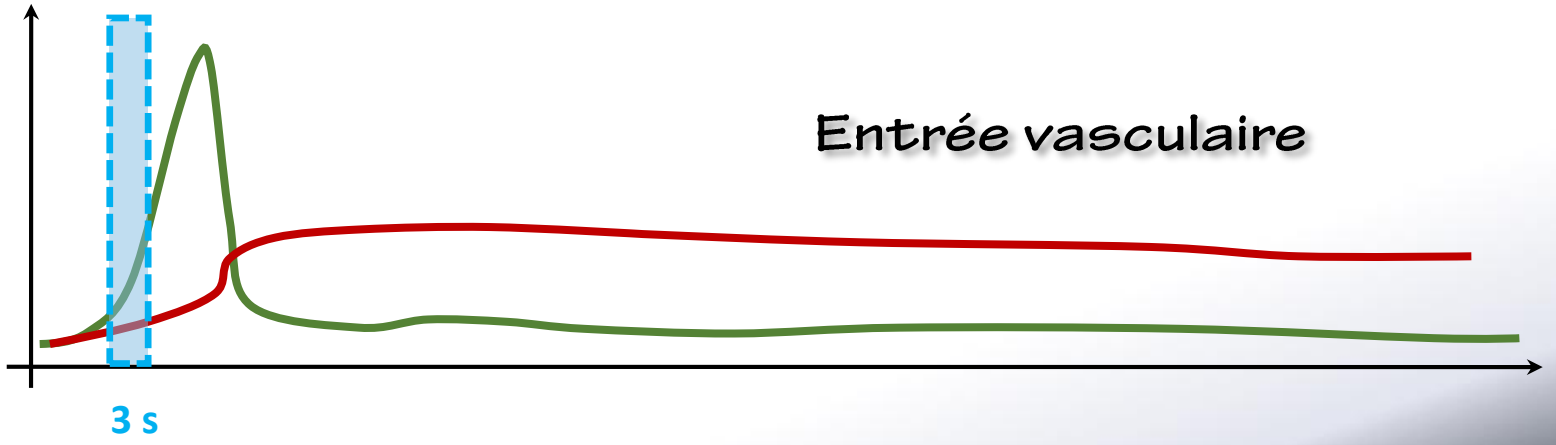
Analyse factorielle



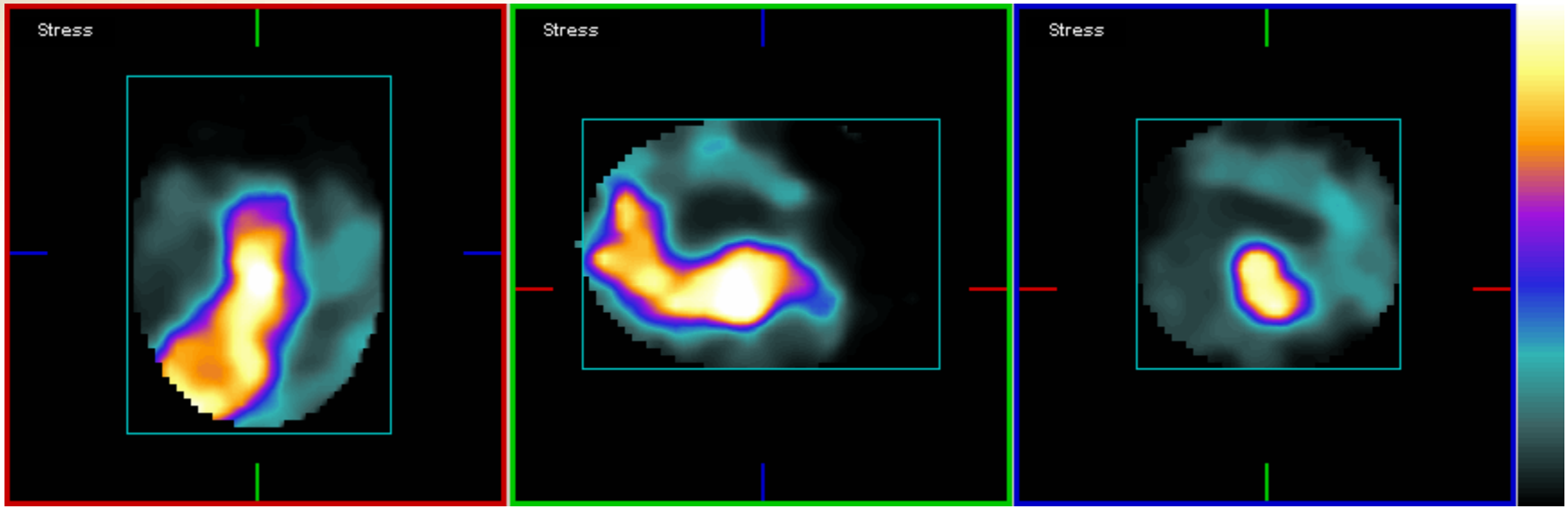


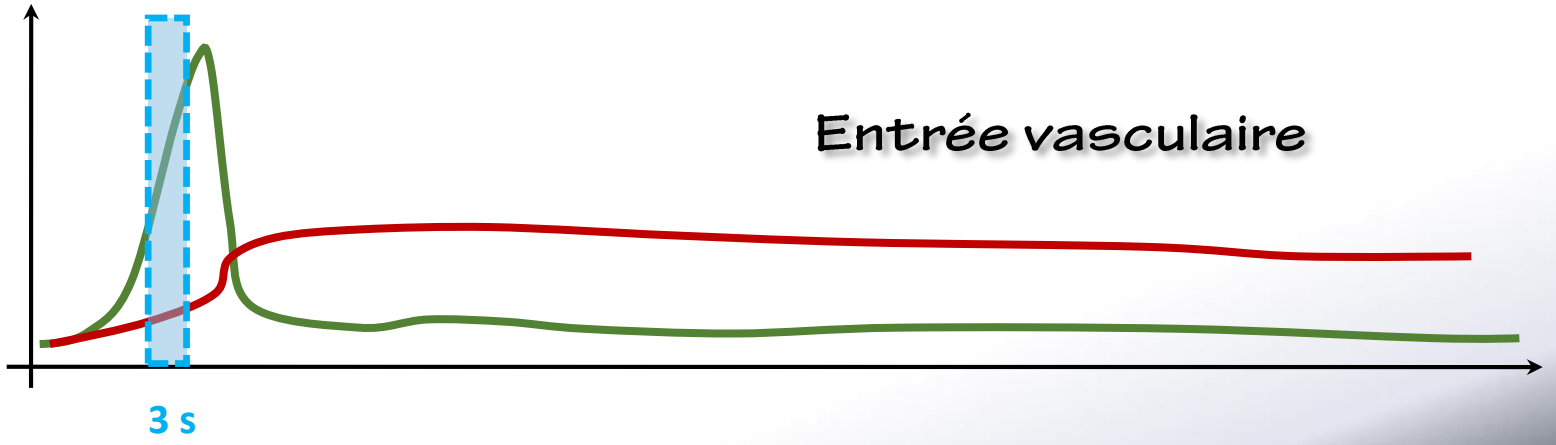
Analyse factorielle



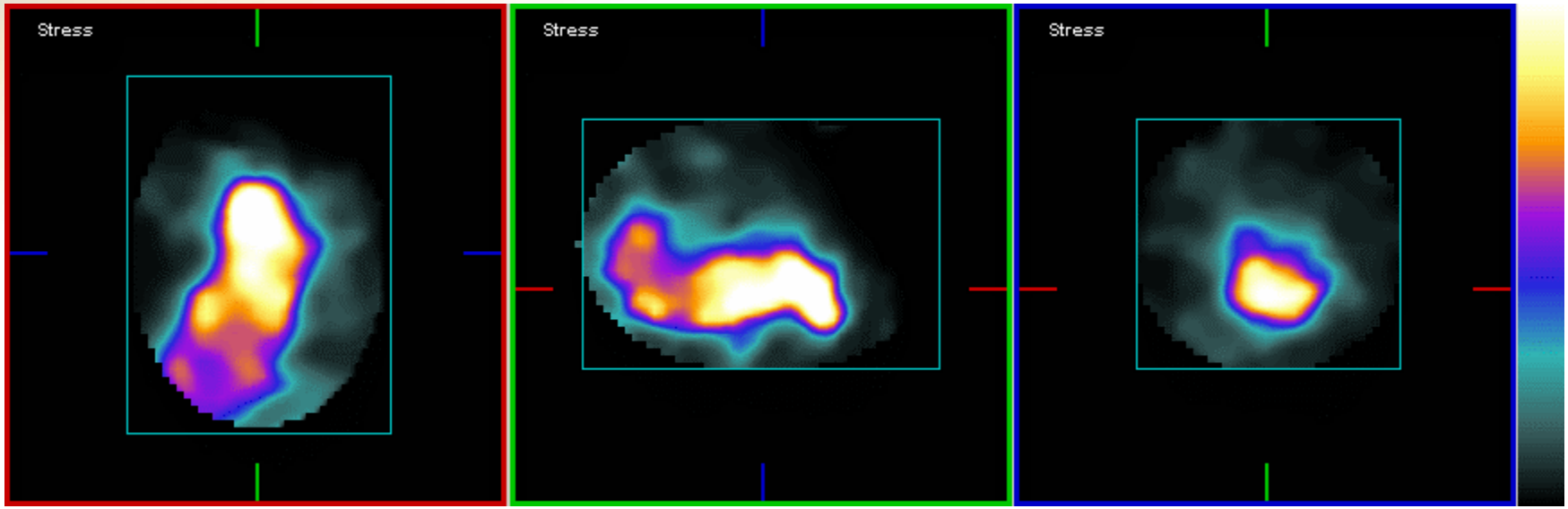


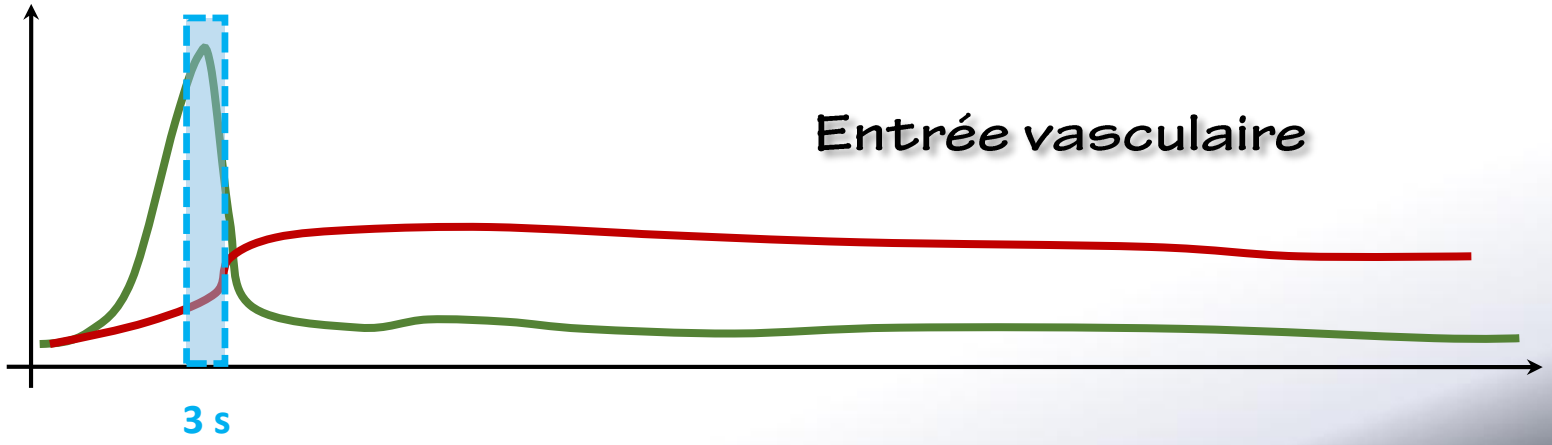
Analyse factorielle



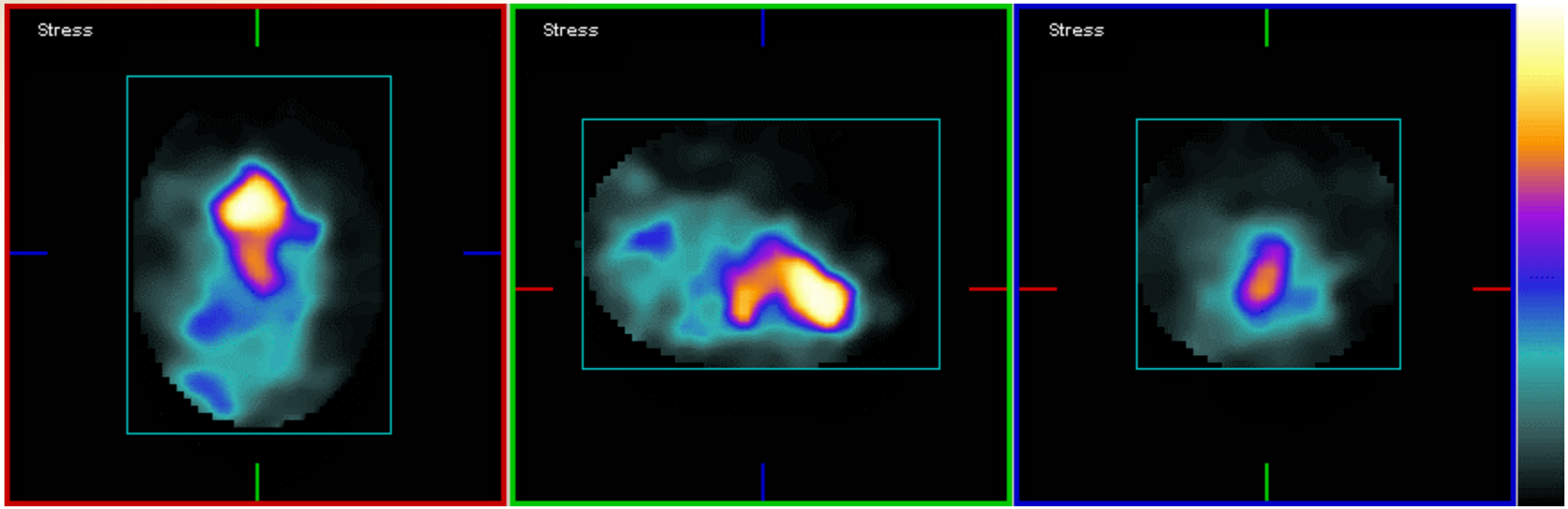


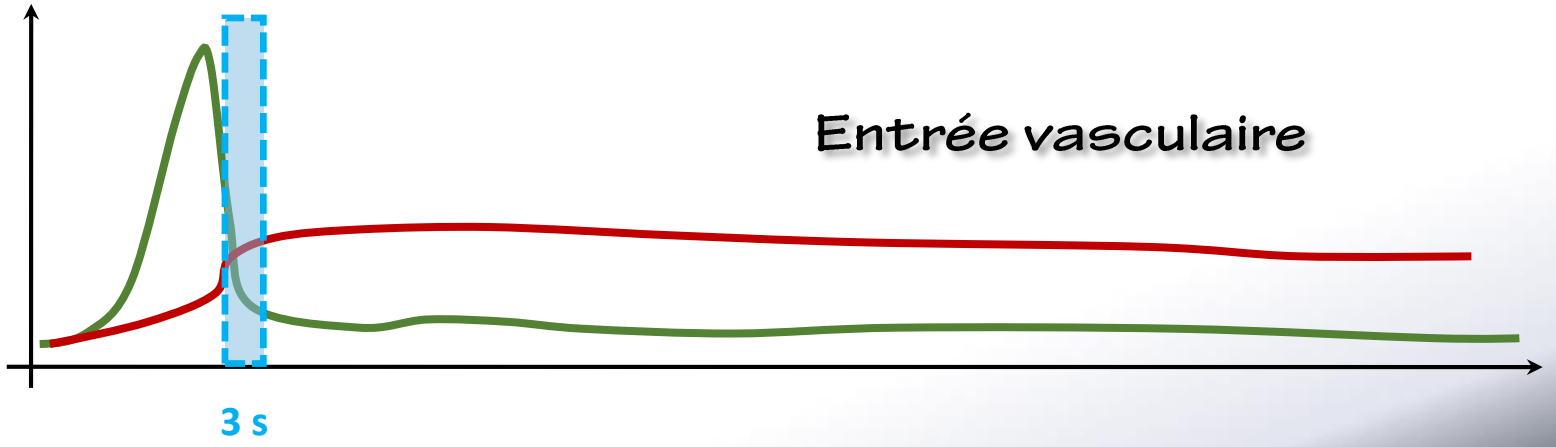
Analyse factorielle



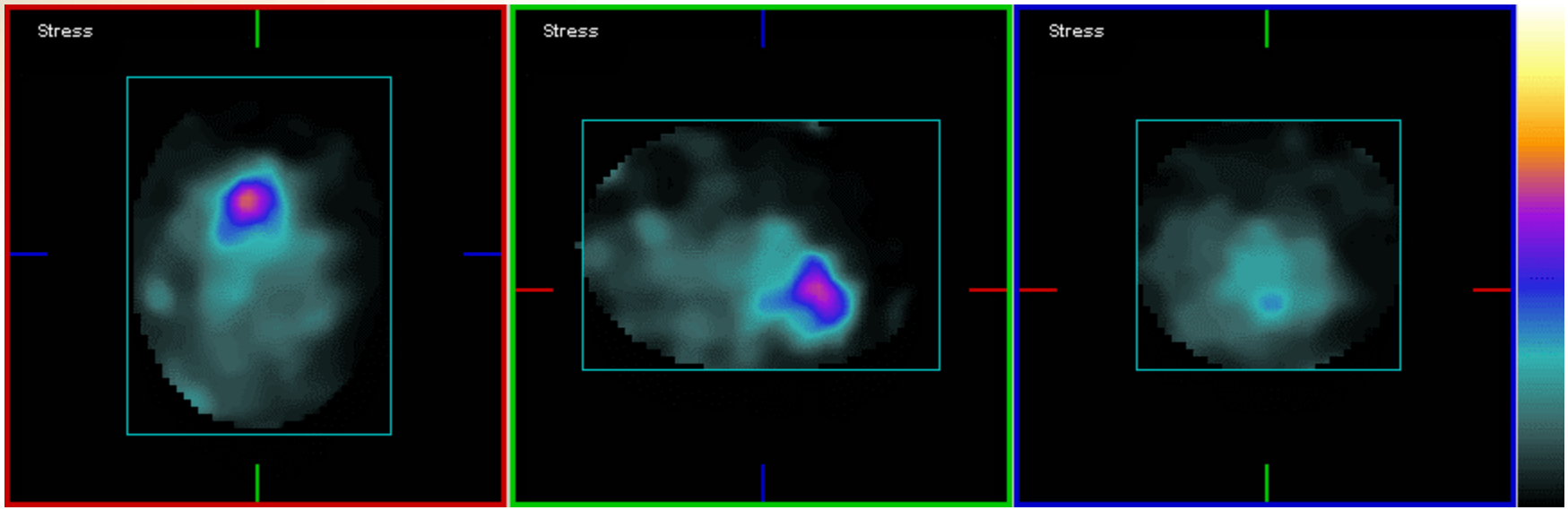


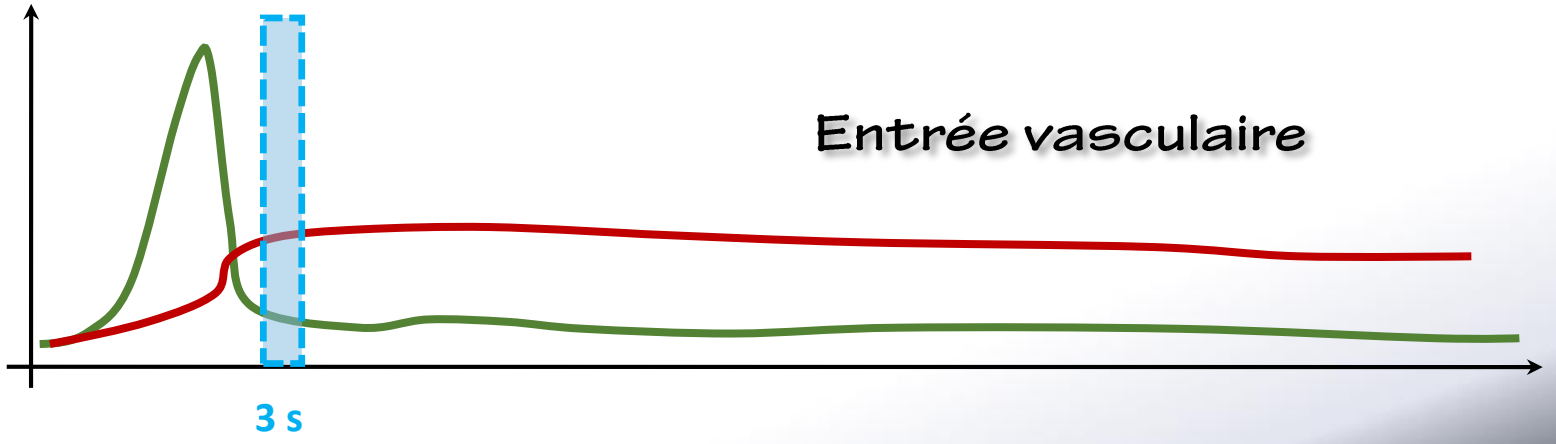
Analyse factorielle



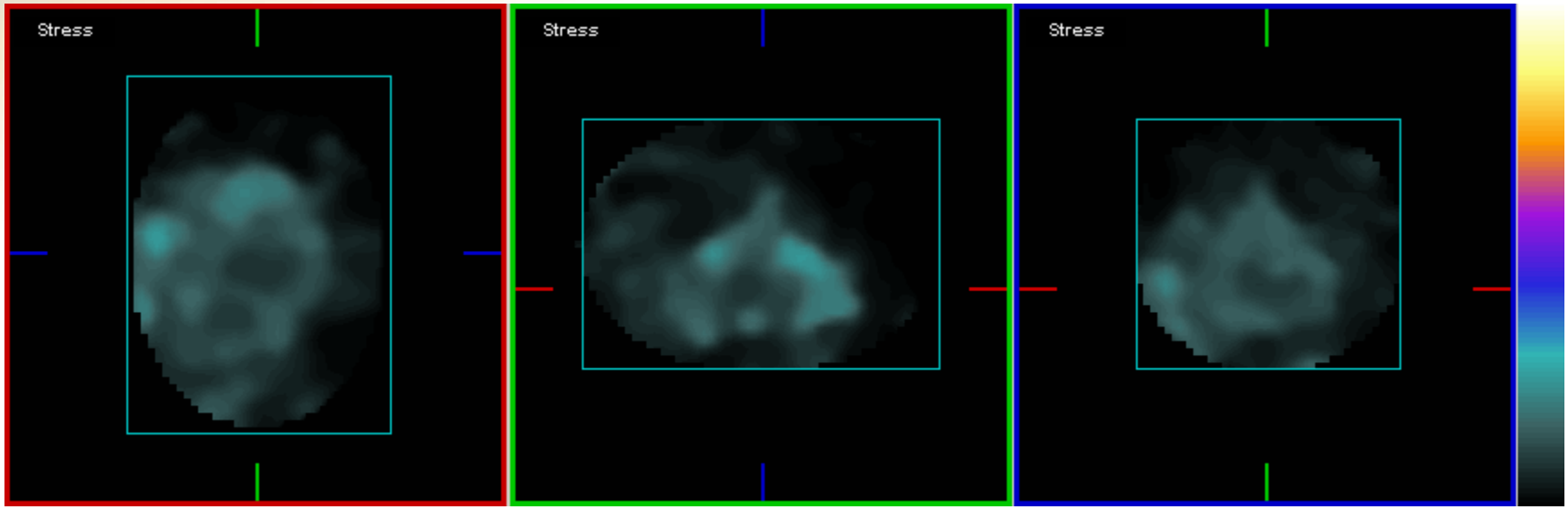


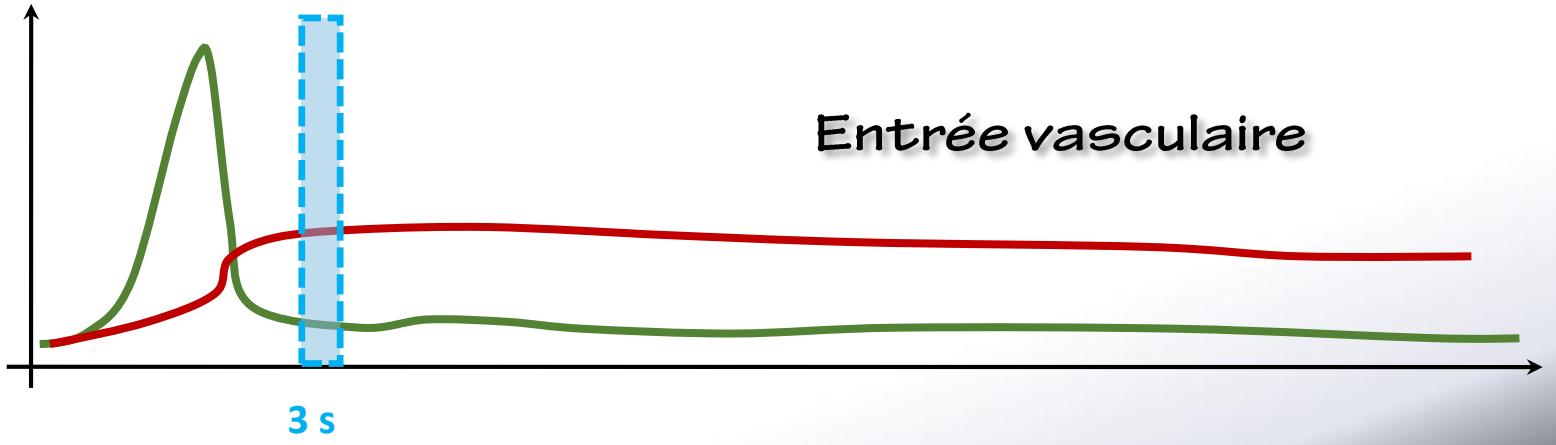
Analyse factorielle



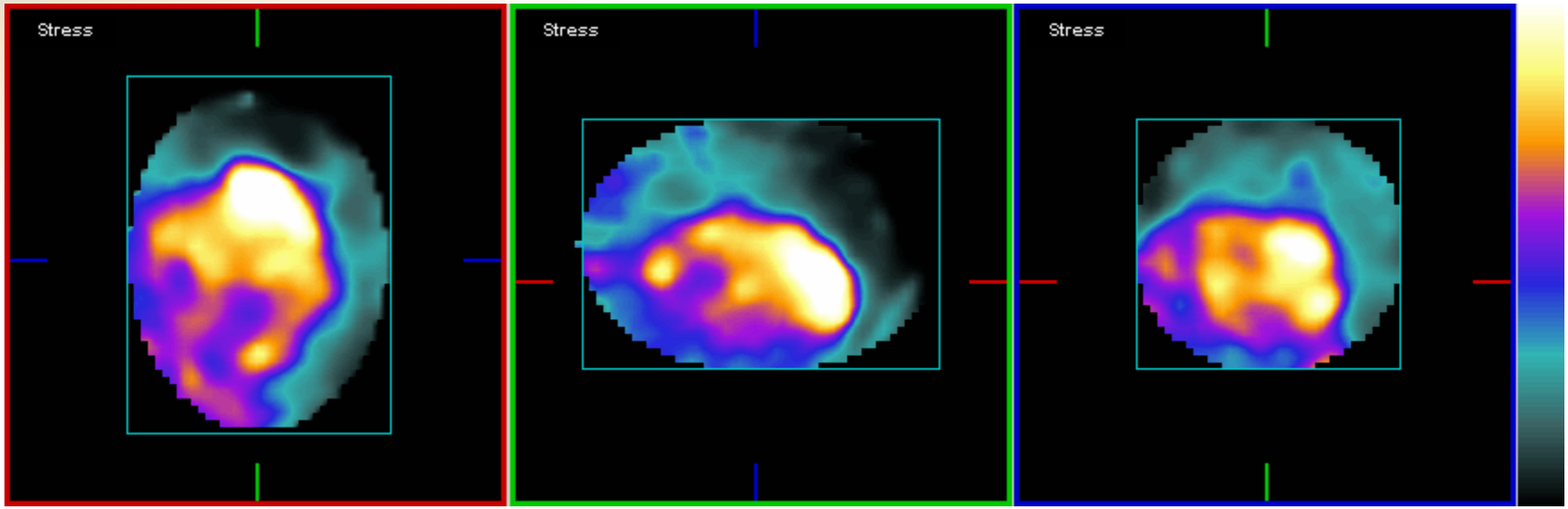


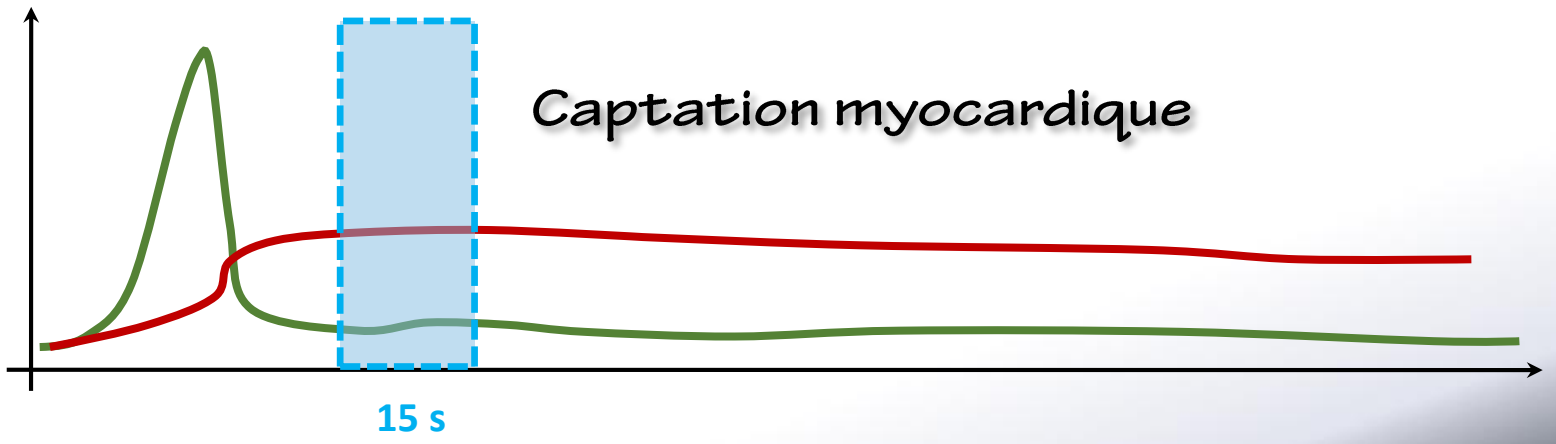
Analyse factorielle



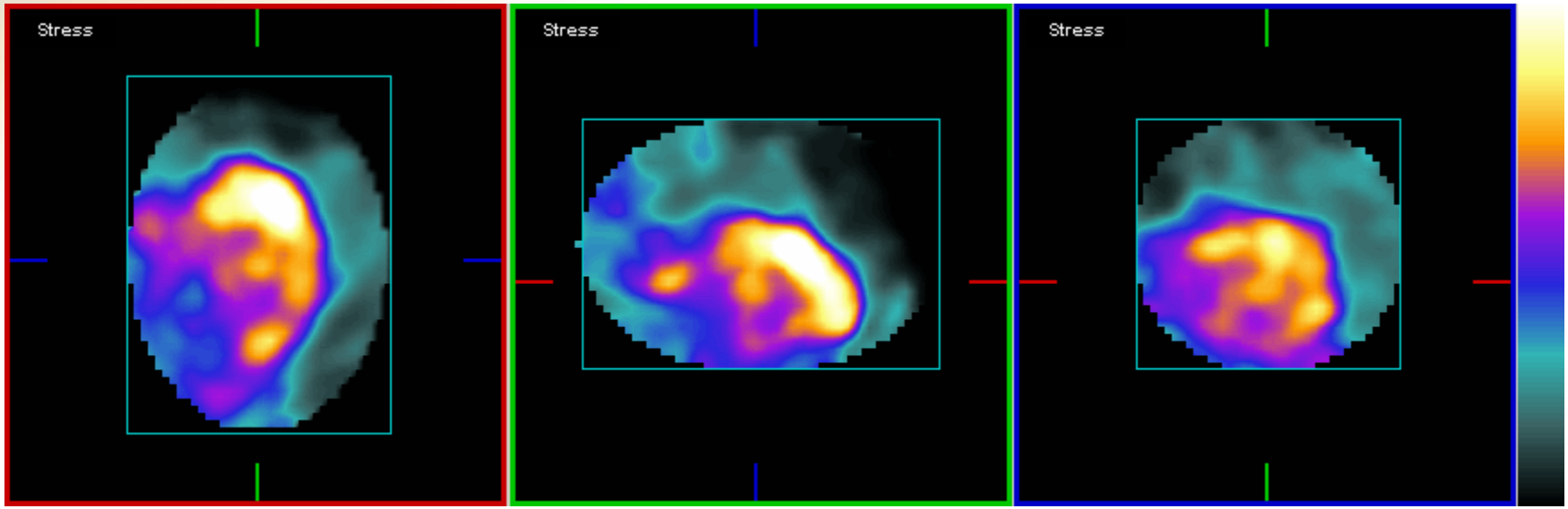


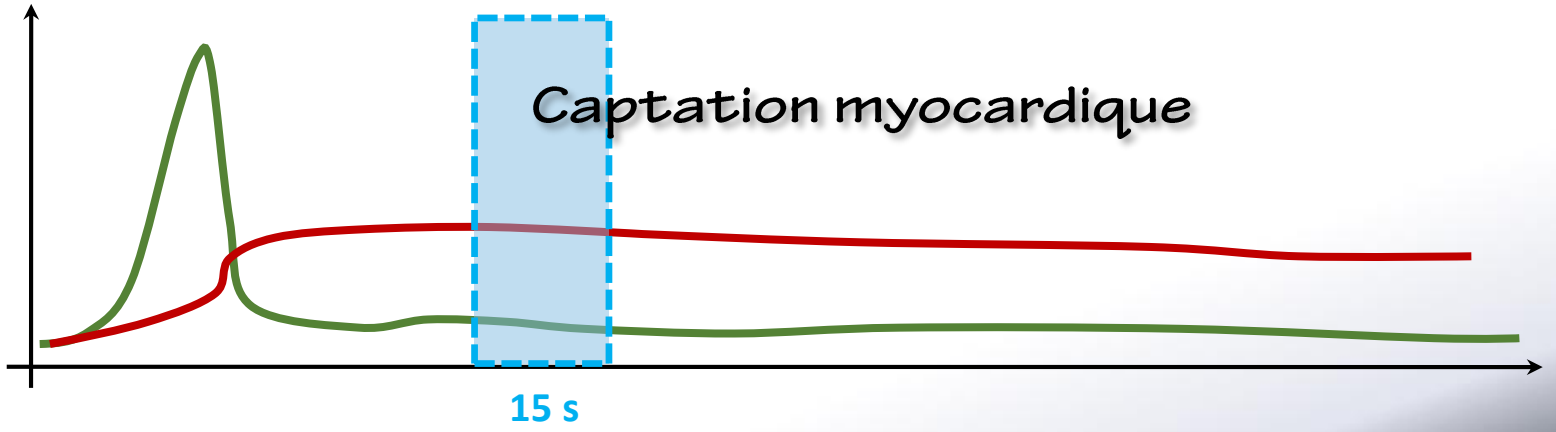
Analyse factorielle



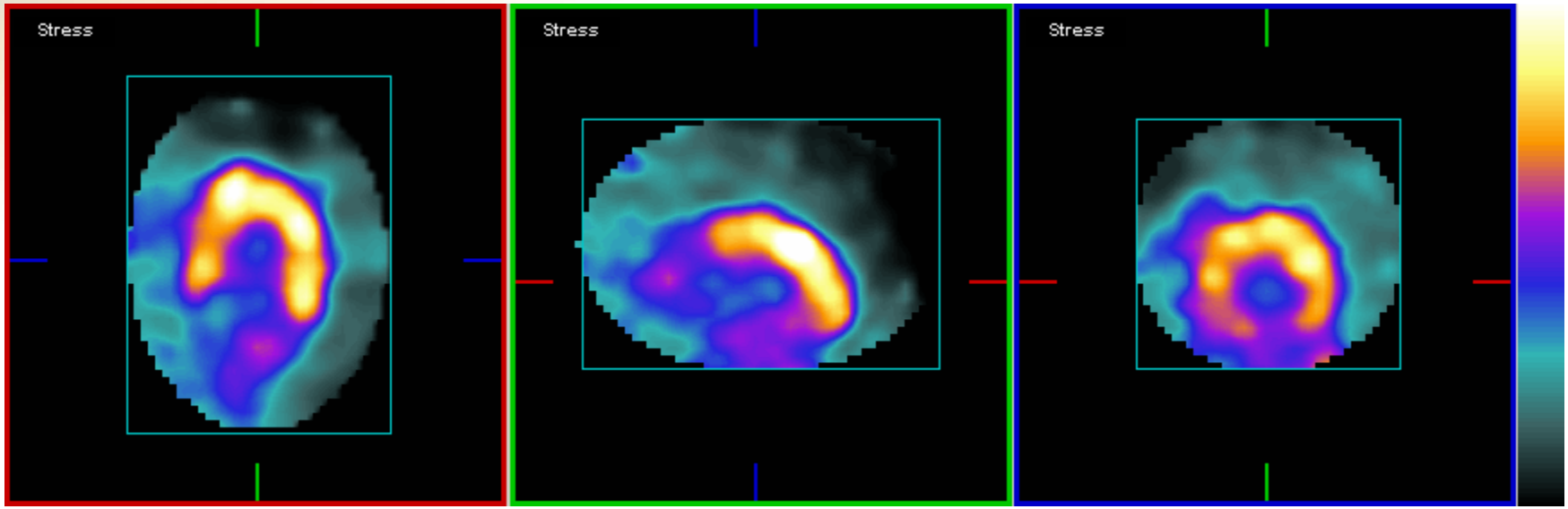


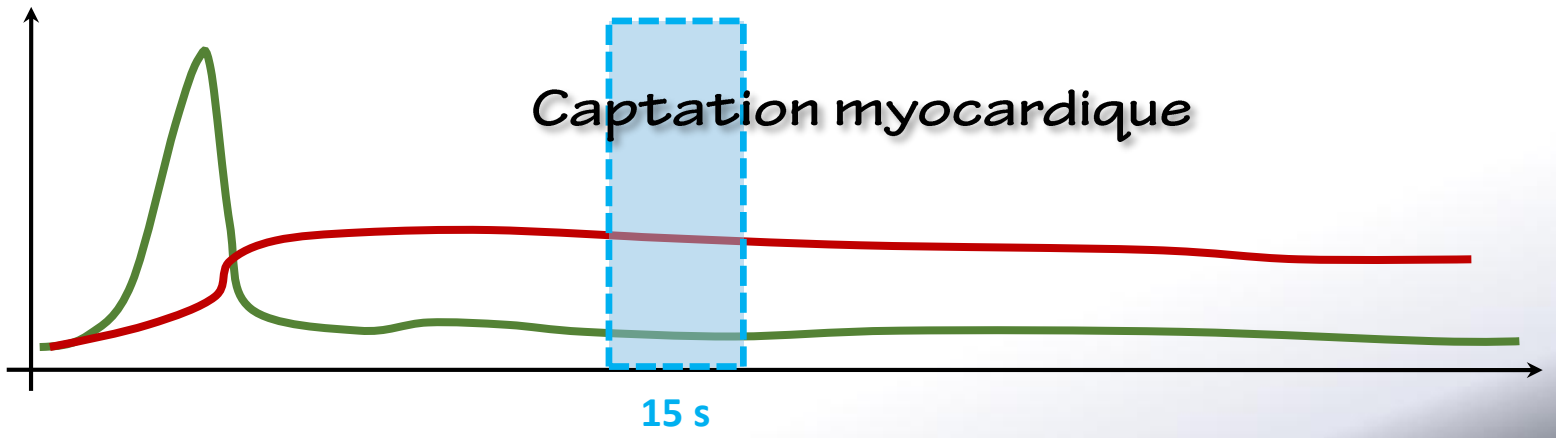
Analyse factorielle



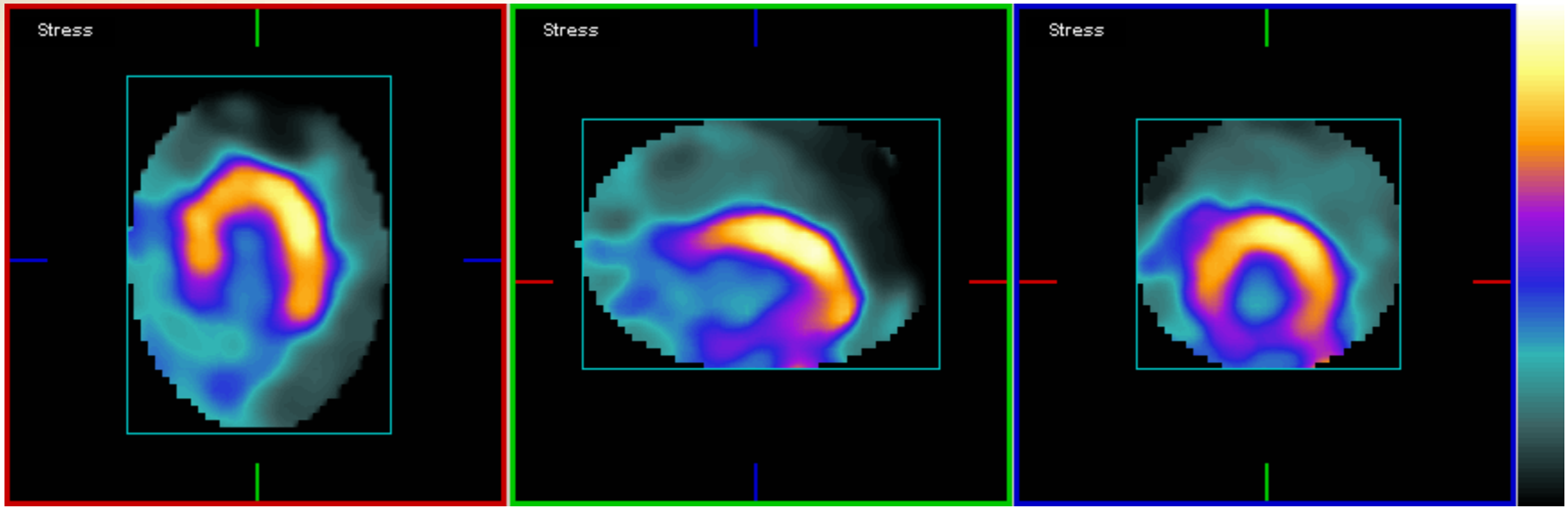


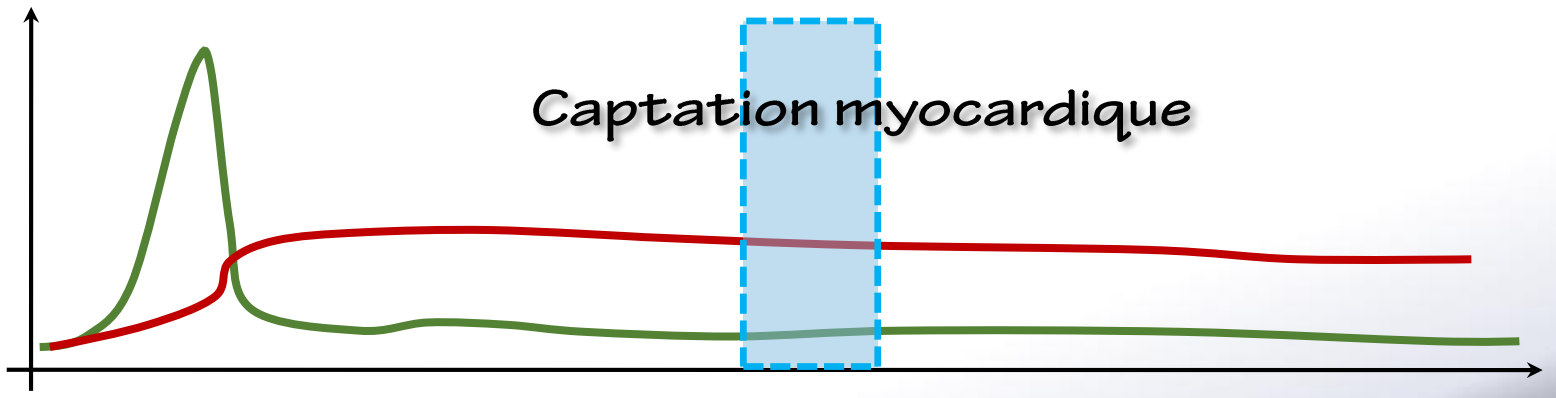
Analyse factorielle



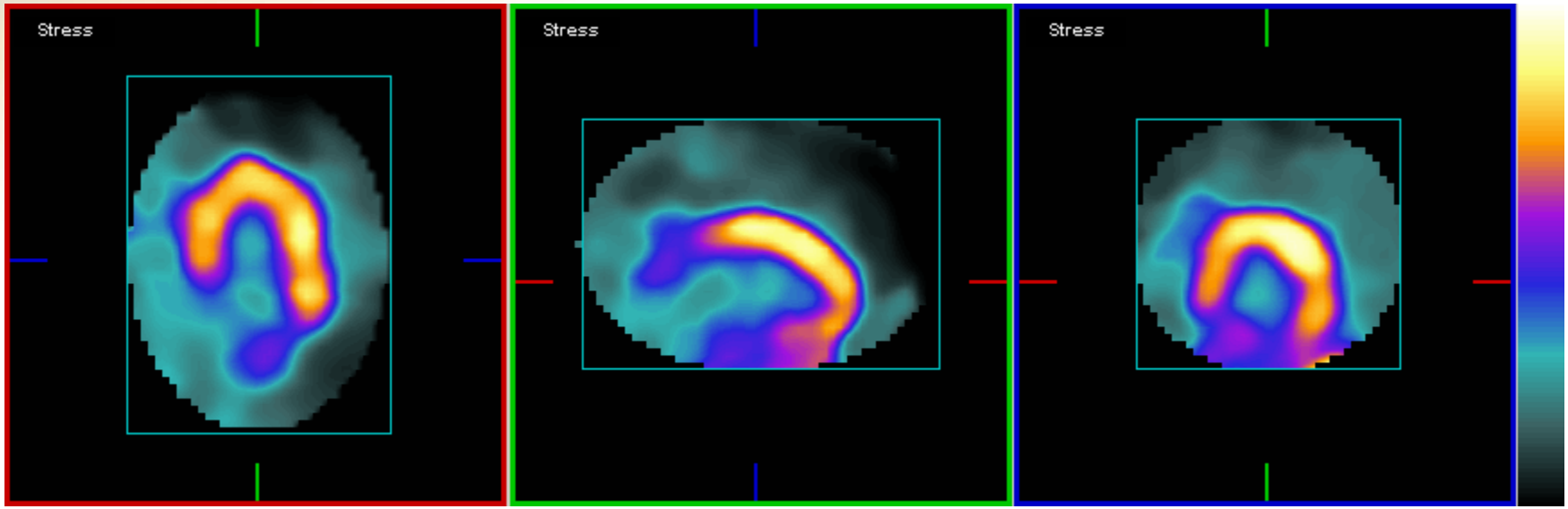


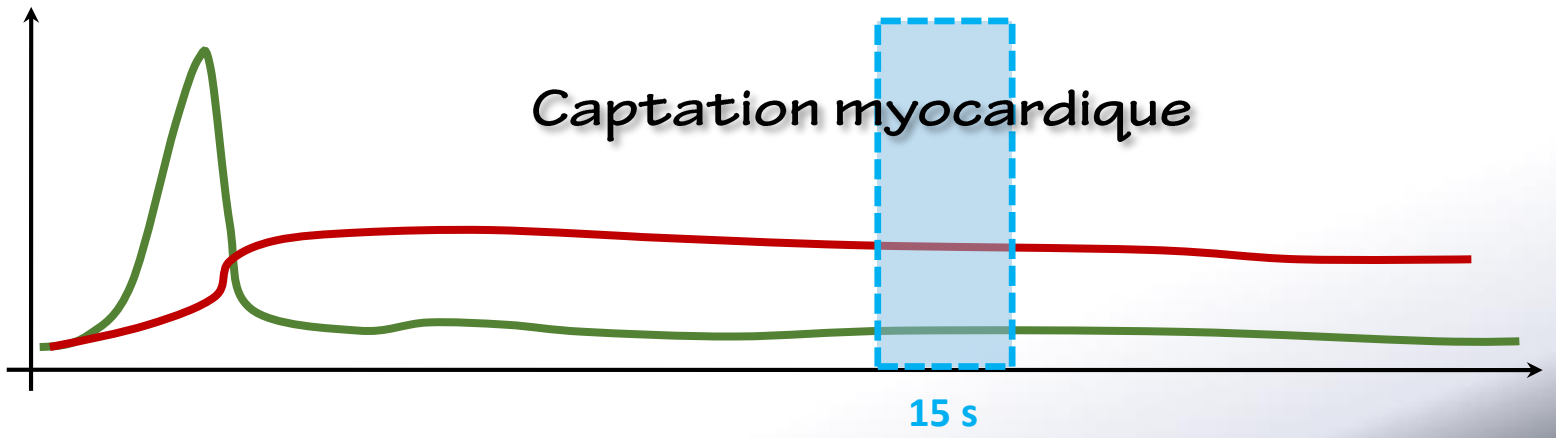
Analyse factorielle



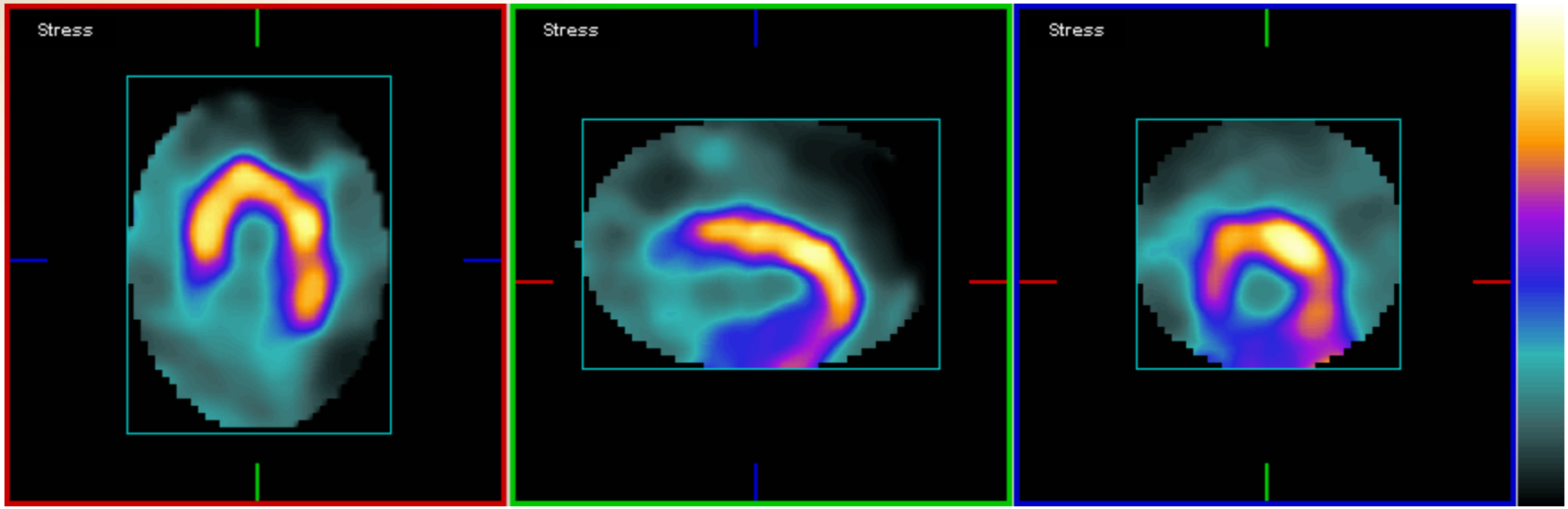


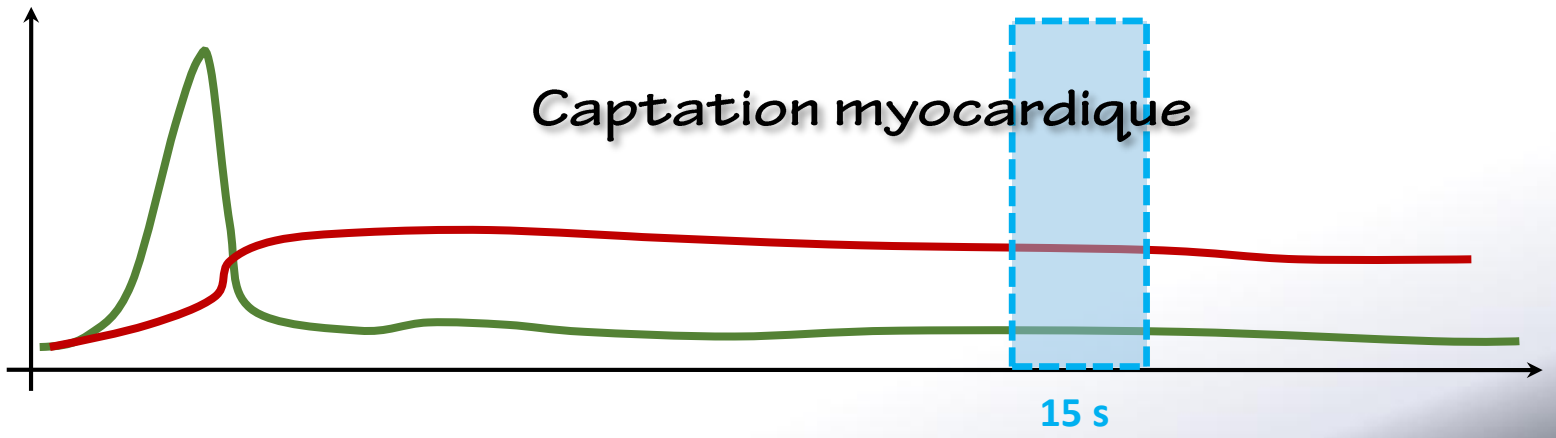
Analyse factorielle



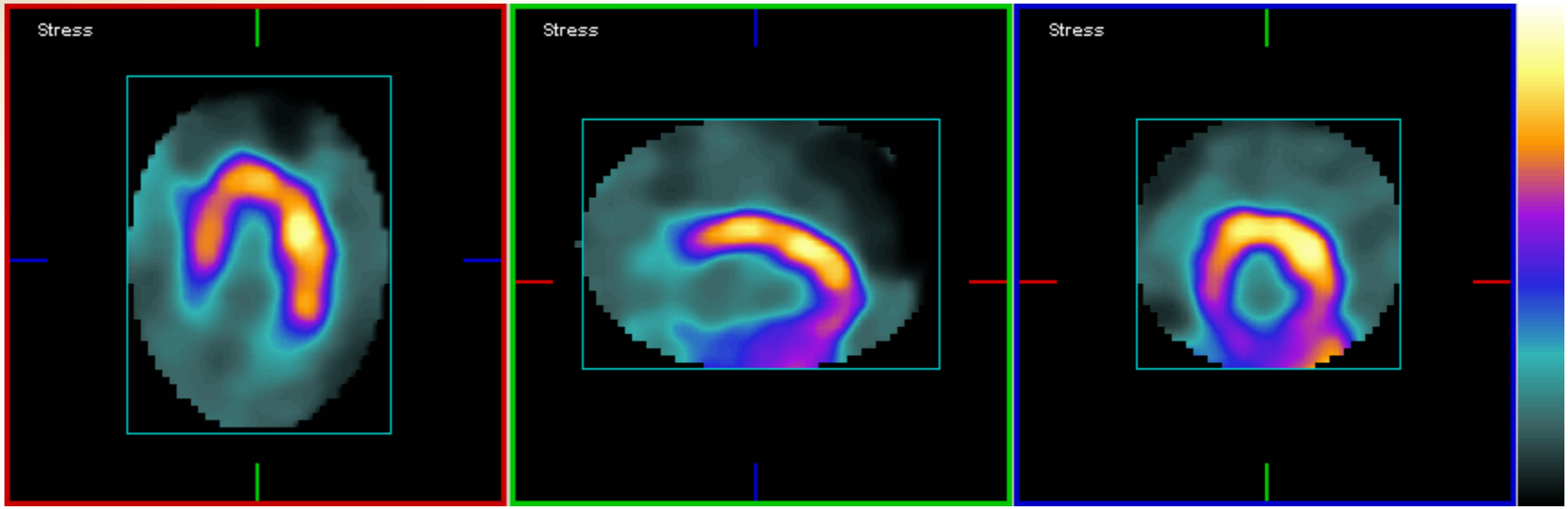


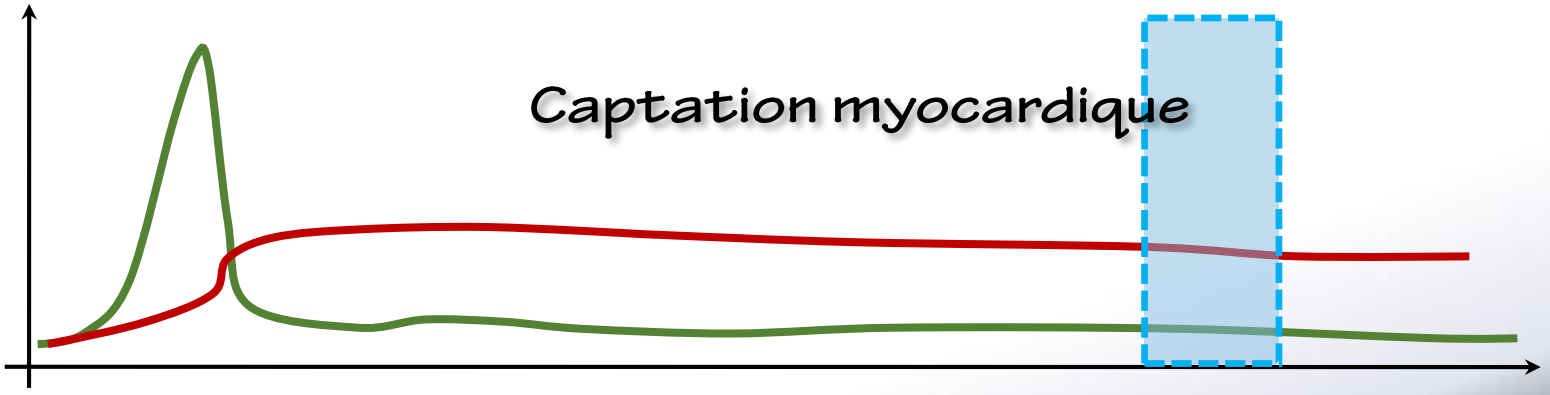
Analyse factorielle



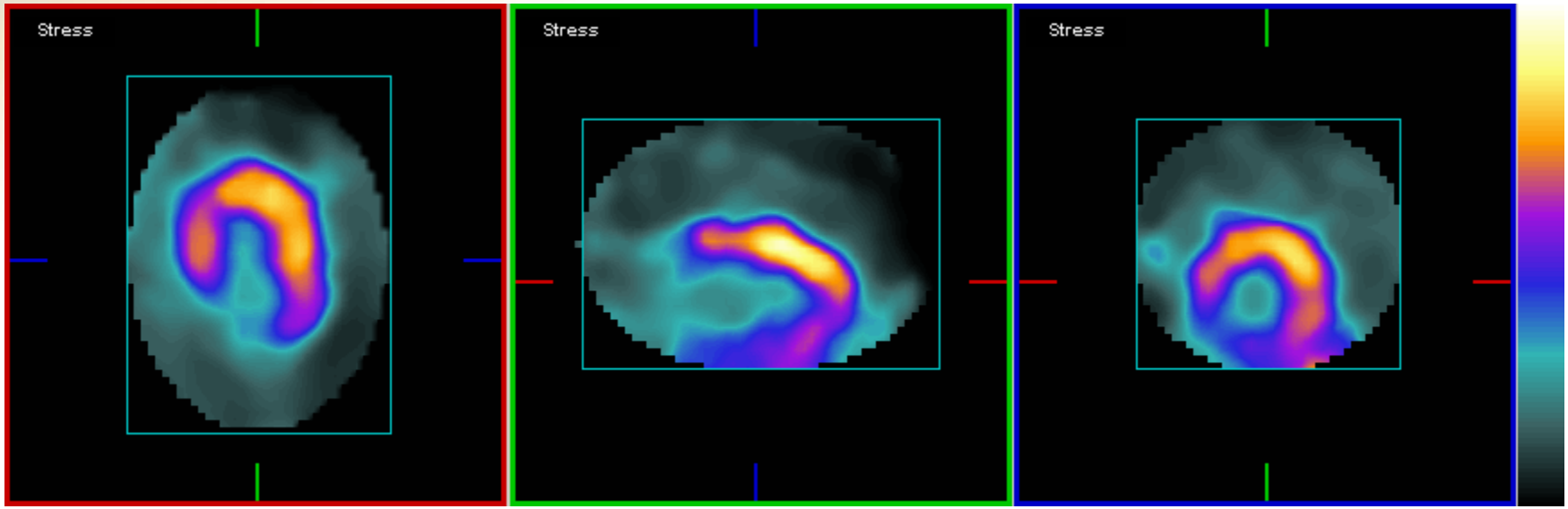


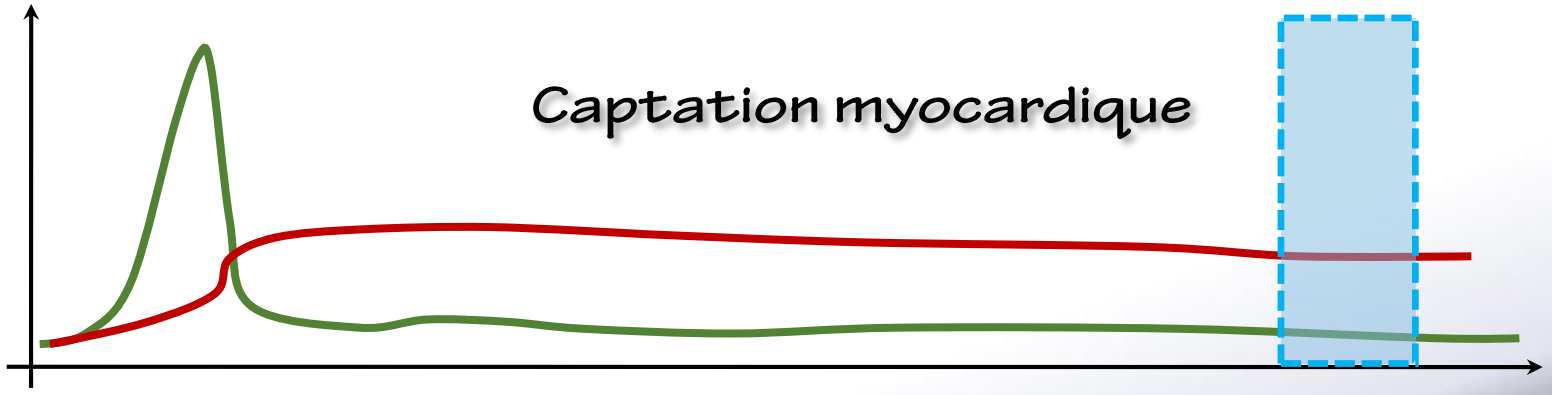
Analyse factorielle





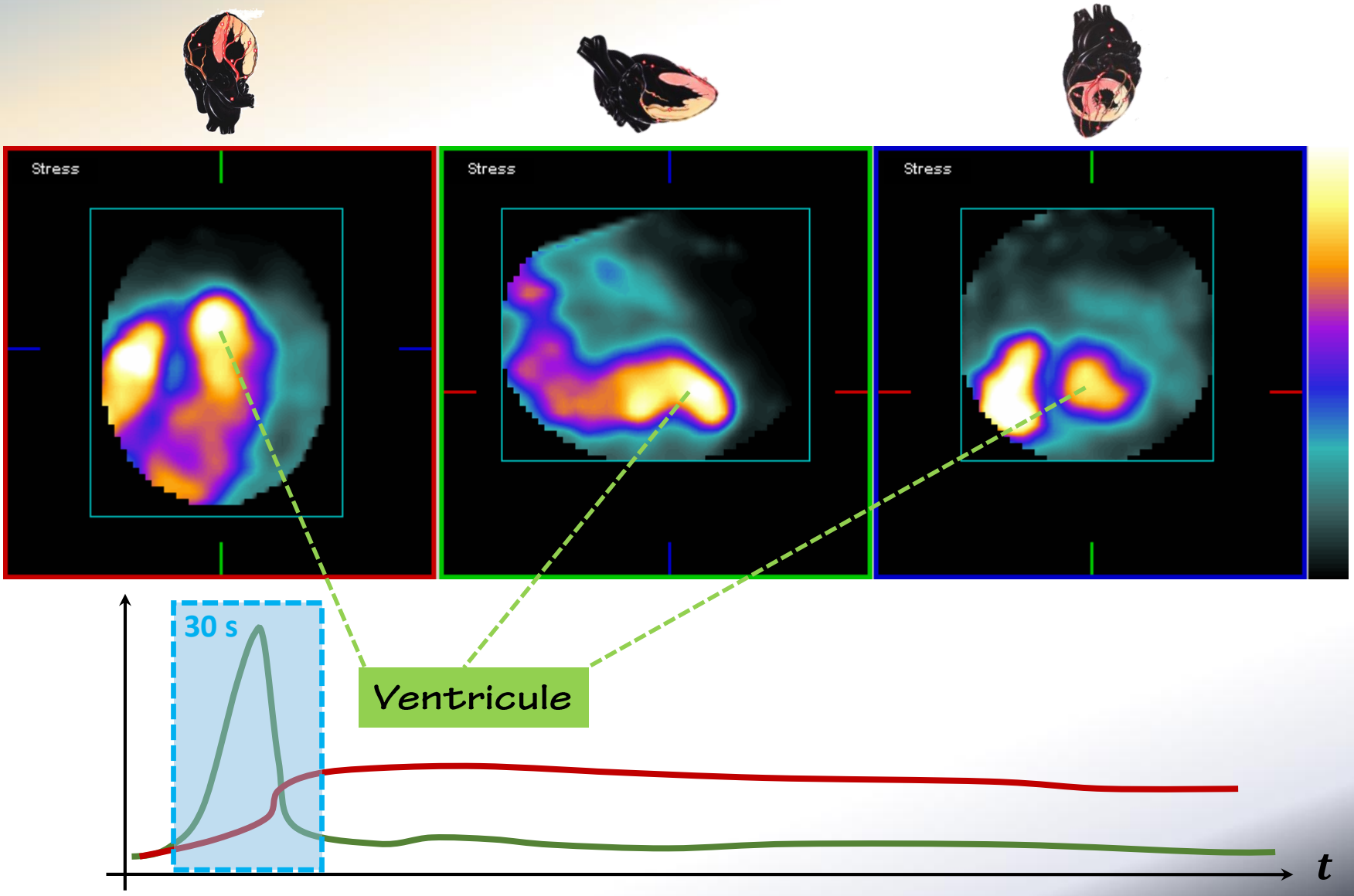
Analyse factorielle





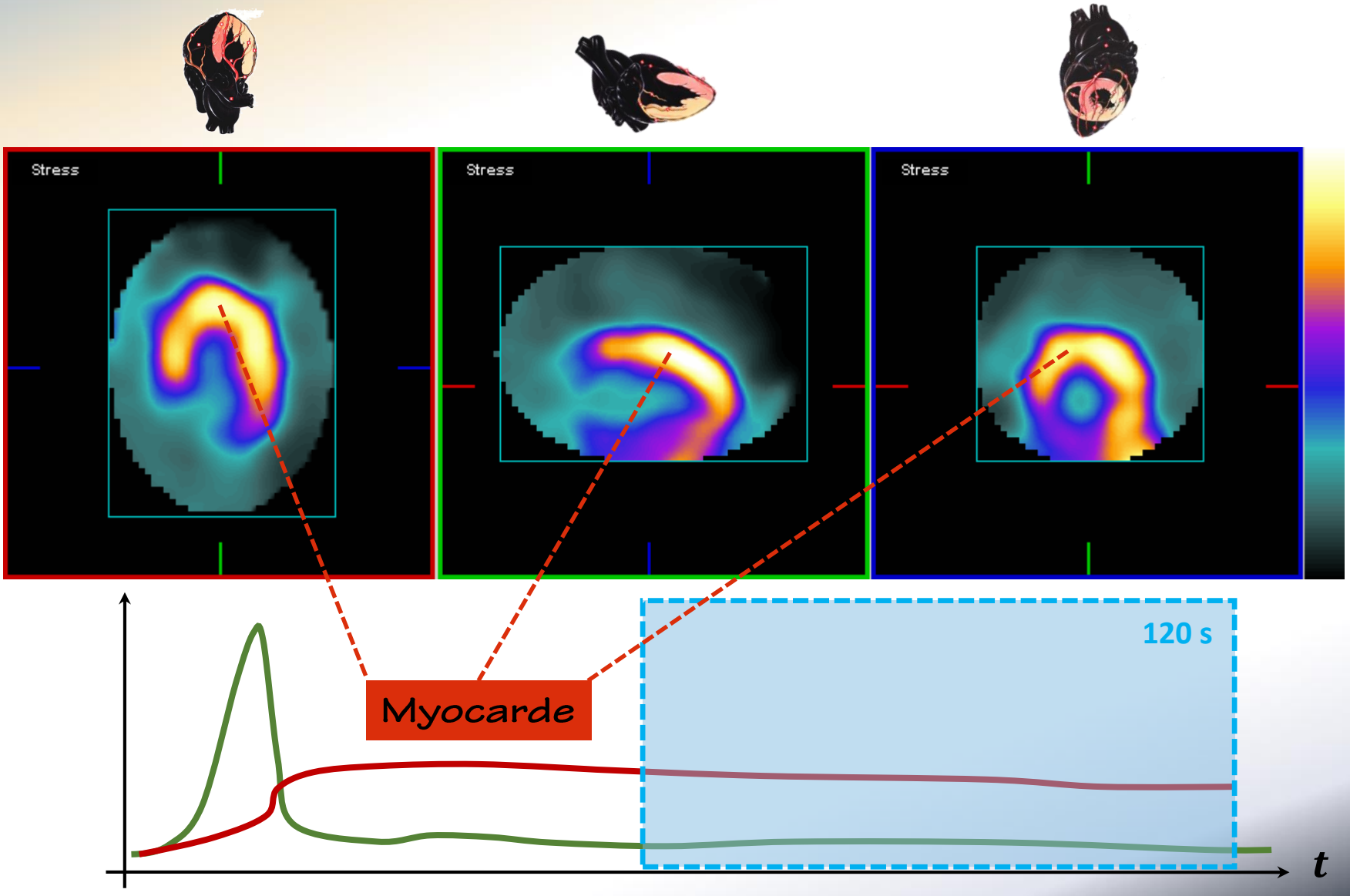
Analyse factorielle

SPECT dynamique



Analyse factorielle

SPECT dynamique



Analyse factorielle

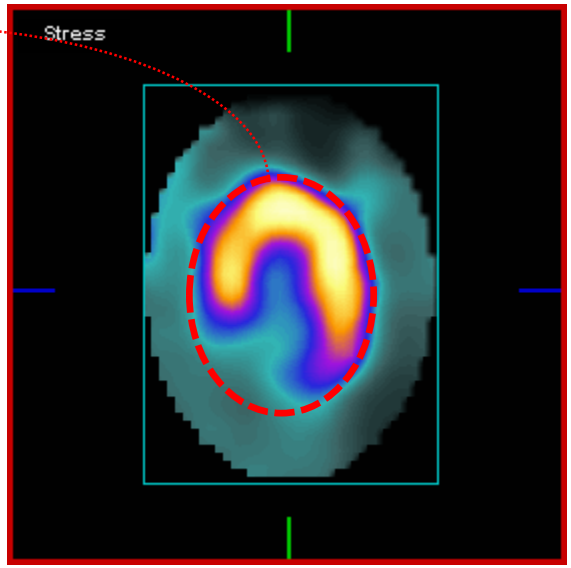
SPECT dynamique

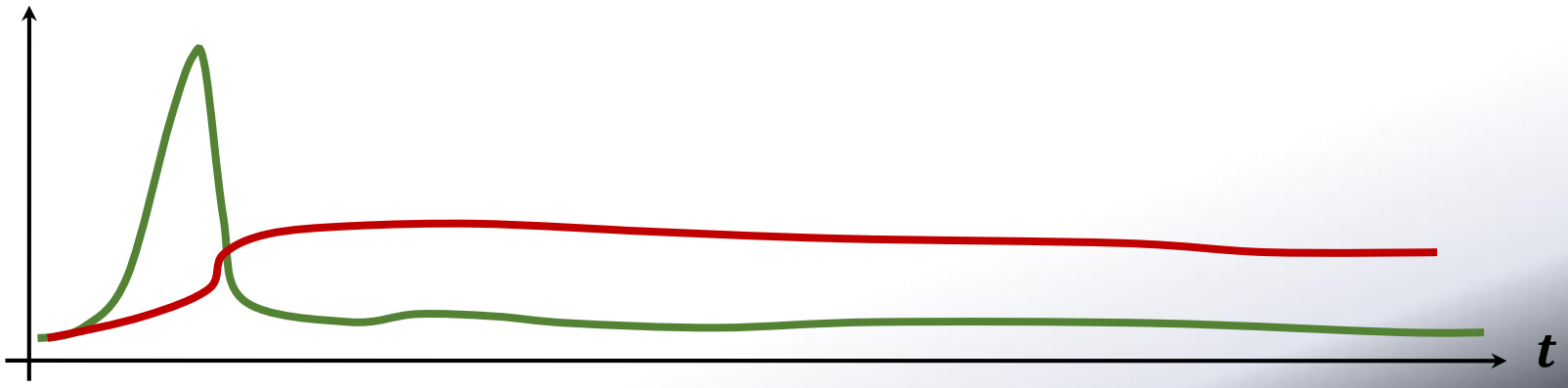
$$\mathbf{M} = \begin{bmatrix} \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \end{bmatrix}$$

voxels

"sujets"

t





Analyse factorielle

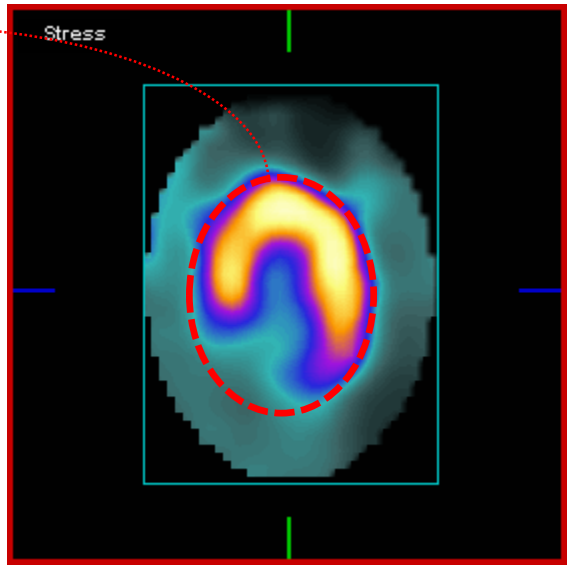
SPECT dynamique

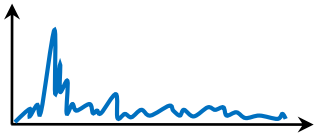
$$\mathbf{M} = \begin{bmatrix} \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \end{bmatrix}$$

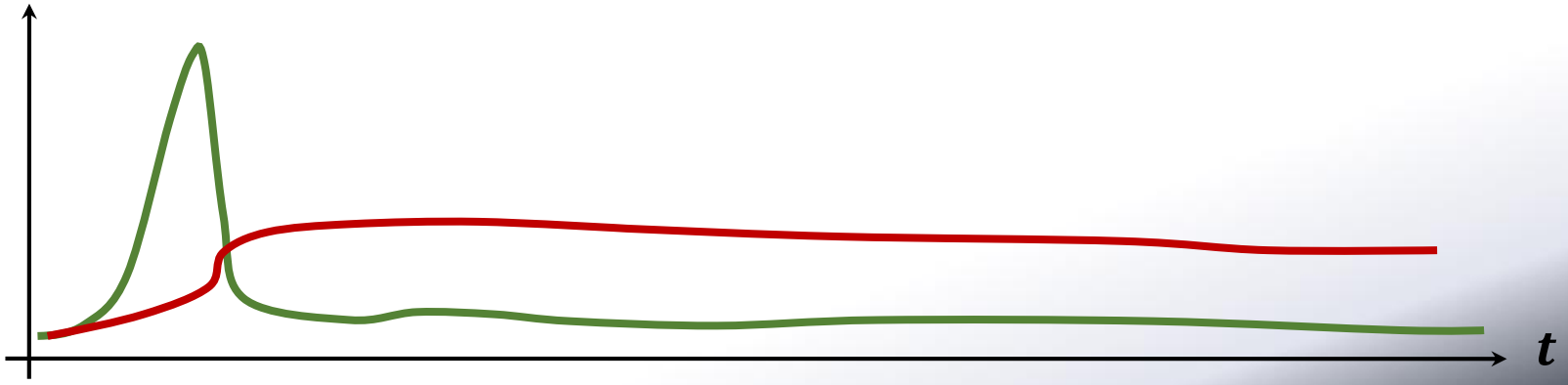
voxels

"sujets"

t



vox_n  $= \alpha_1 \vec{u}_1 + \alpha_2 \vec{u}_2$



Analyse factorielle

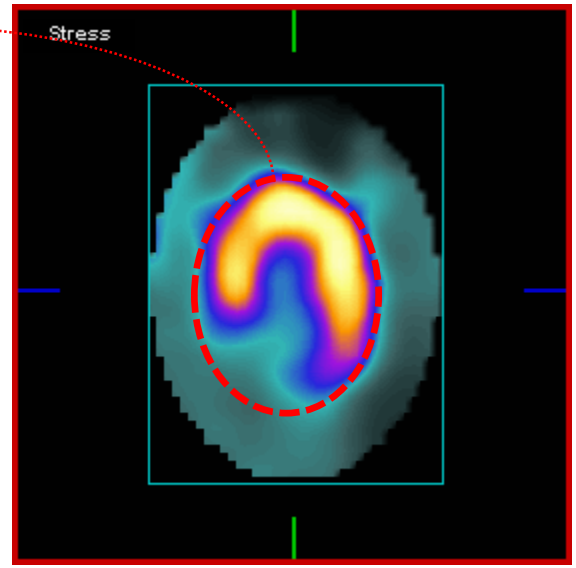
SPECT dynamique

$$\mathbf{M} = \begin{bmatrix} \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \end{bmatrix}$$

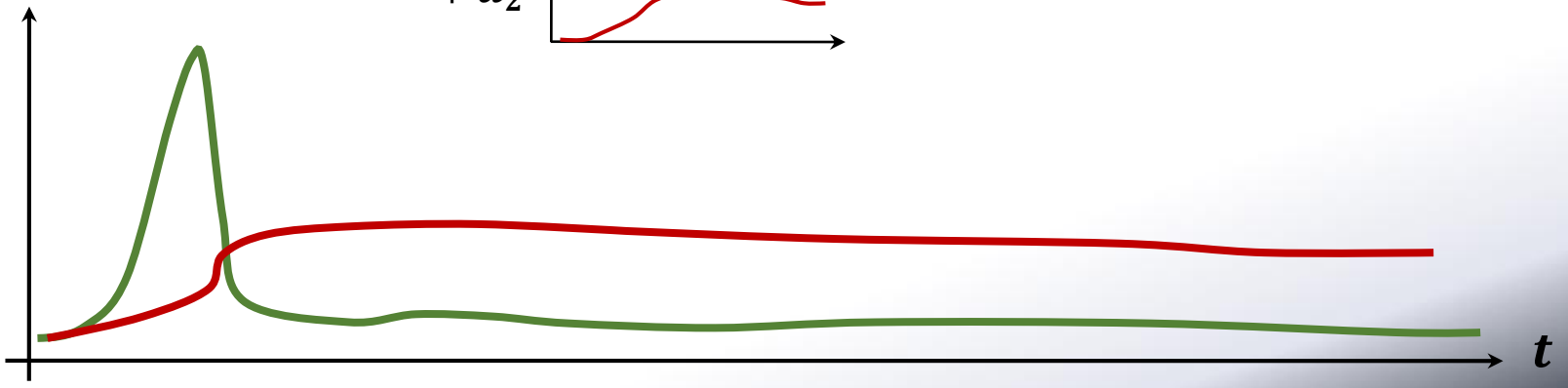
voxels

"sujets"

t



vox_n $= \alpha_1 \vec{u}_1 + \alpha_2 \vec{u}_2$



Analyse factorielle

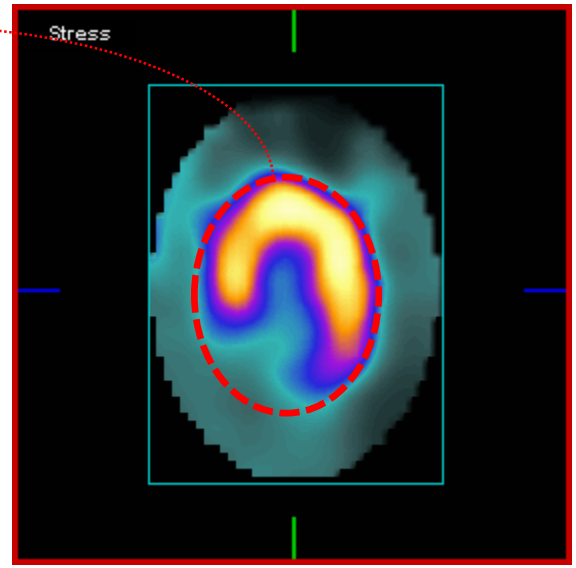
SPECT dynamique

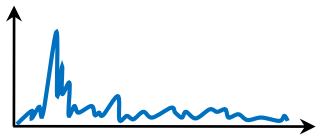
$$\mathbf{M} = \begin{bmatrix} \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \end{bmatrix}$$

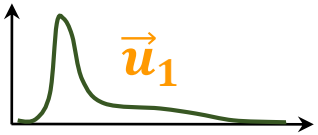
voxels

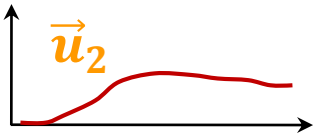
"sujets"

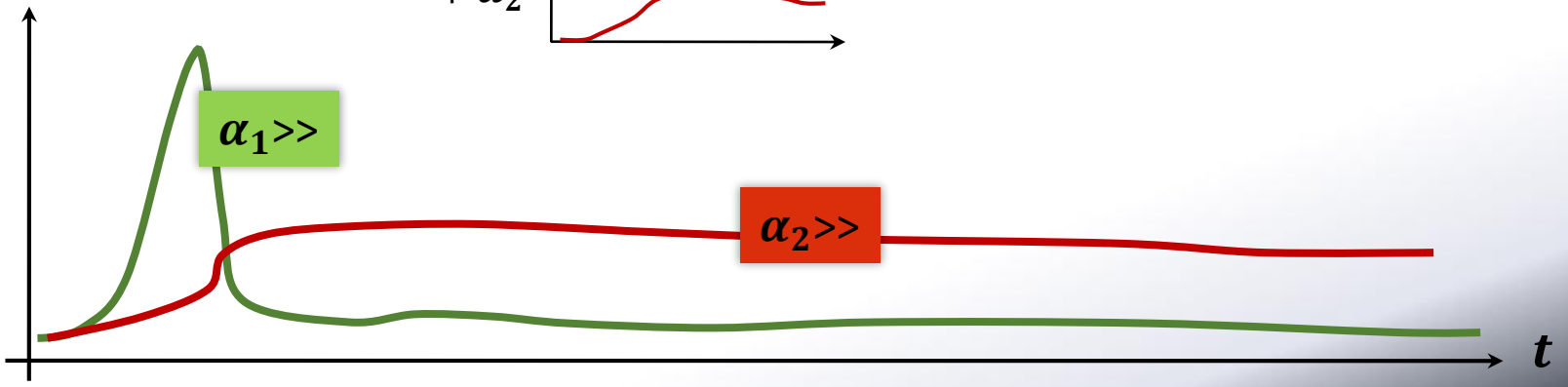
t



vox_n 

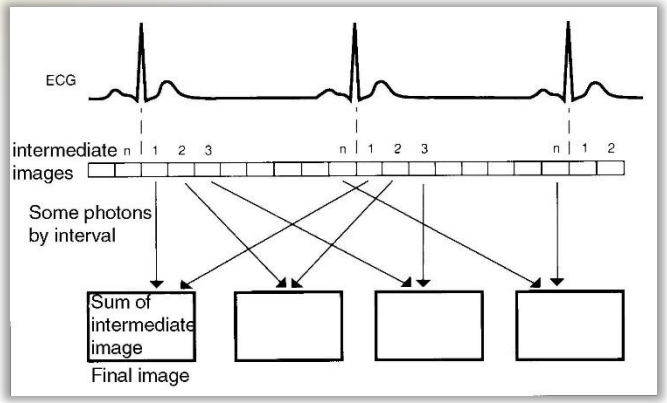
$= \alpha_1$ 

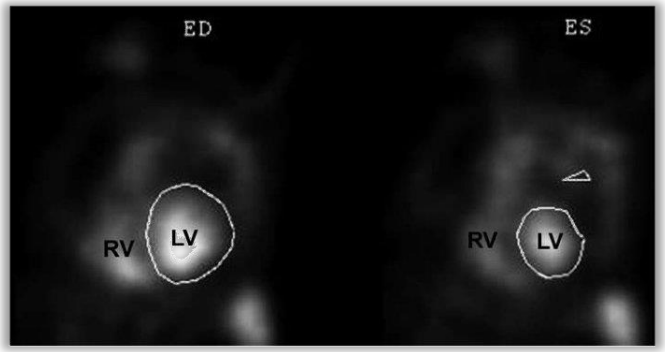
$+ \alpha_2$ 

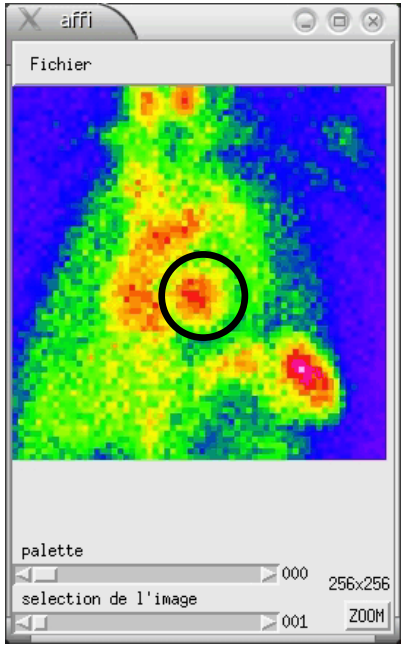


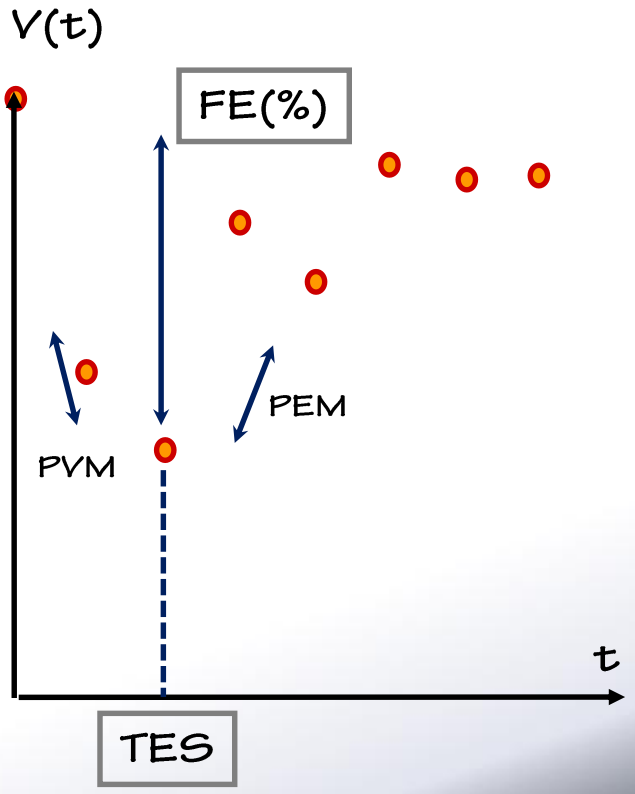
Ventriculographie isotopique

- Marquage des GR au ^{99m}Tc
- Synchronisation ECG
- Analyse de CTA globale / locale









Ventriculographie isotopique

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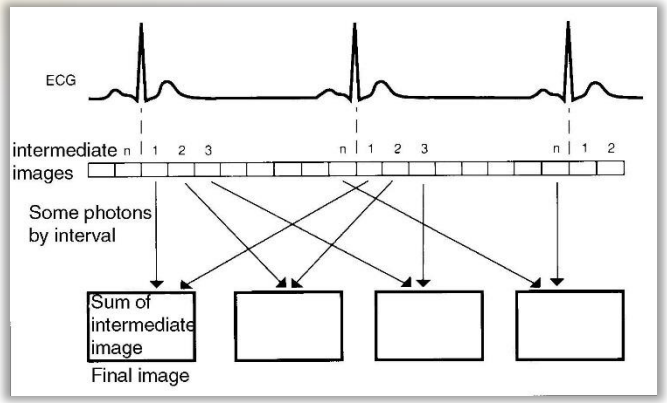
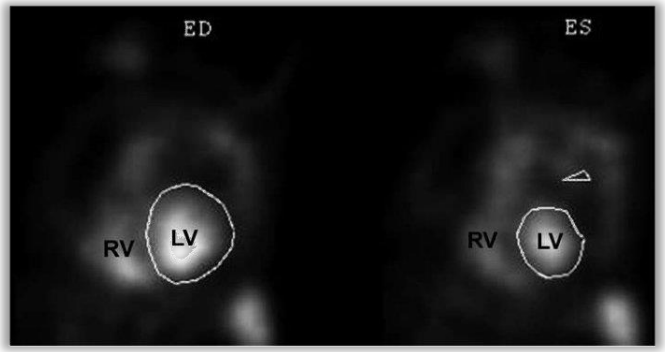
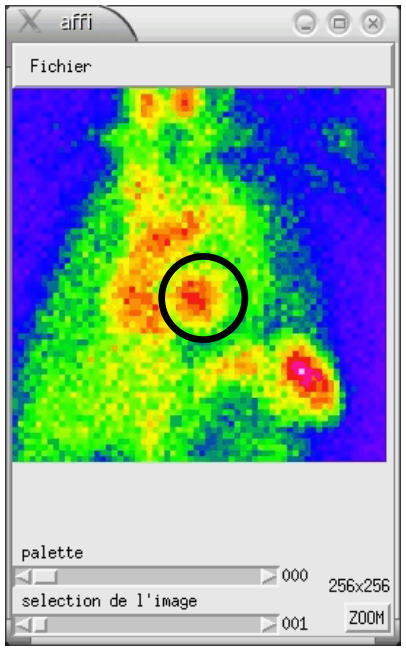
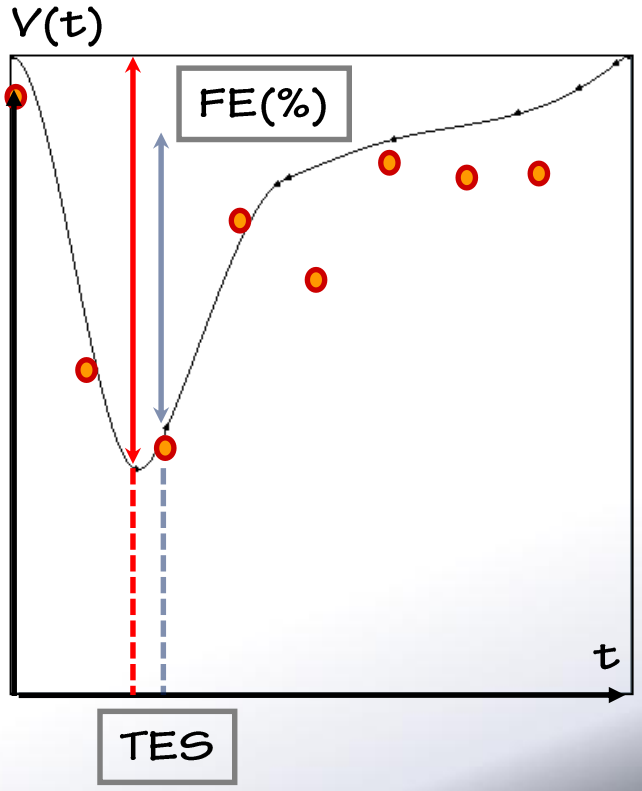








Ventriculographie isotopique

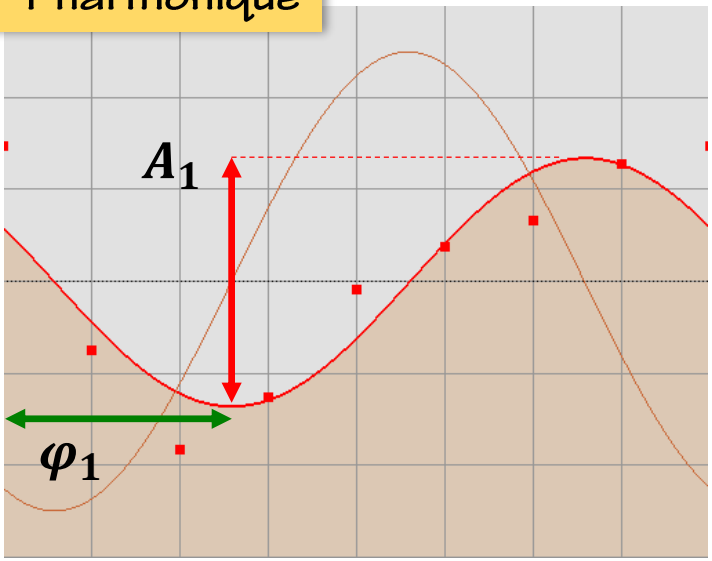
FIT HARMONIQUE

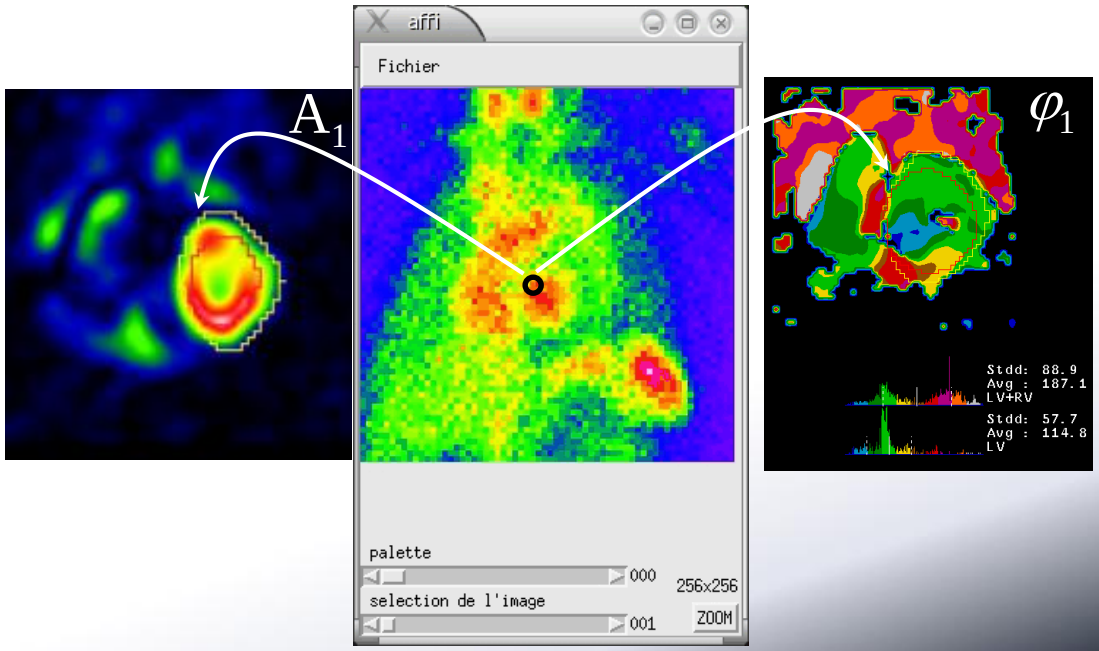
$$s(t) = \frac{1}{N}\sum_{k=0}^{N-1} \hat{s}(k).e^{j.(k.\omega_0)t} = \sum_{k=0}^{N-1} A_k.e^{j.\varphi_k}.e^{j.(k.\omega_0)t} \approx A_0 + A_1 e^{j.(\omega_0 t + \varphi_1)}$$

Ampitude
↳ hypokinésies ?

Phase
↳ dyskinésies ?

1 harmonique





Ventriculographie isotopique

FIT HARMONIQUE

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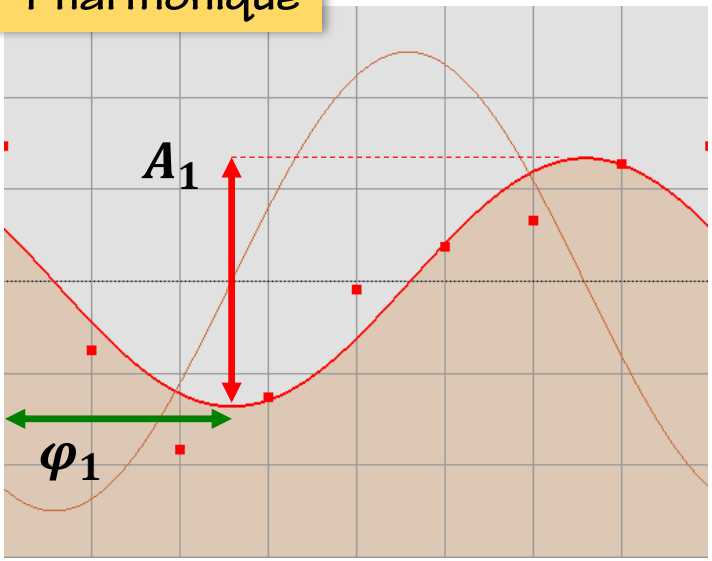
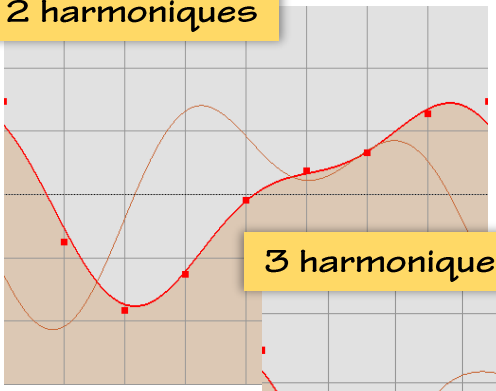
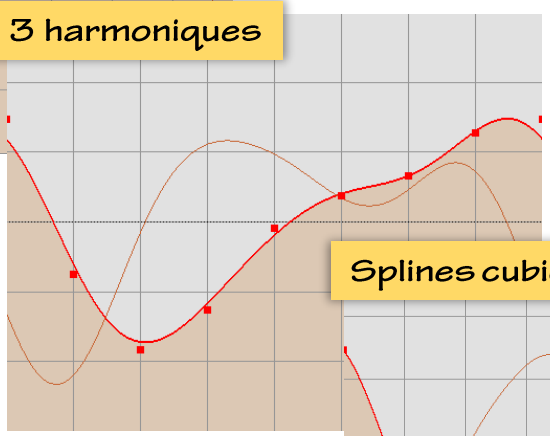
1 harmonique



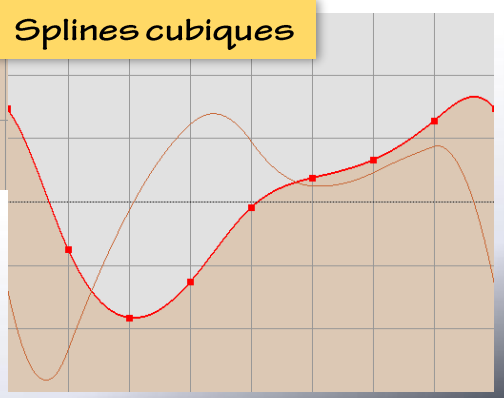
2 harmoniques



3 harmoniques

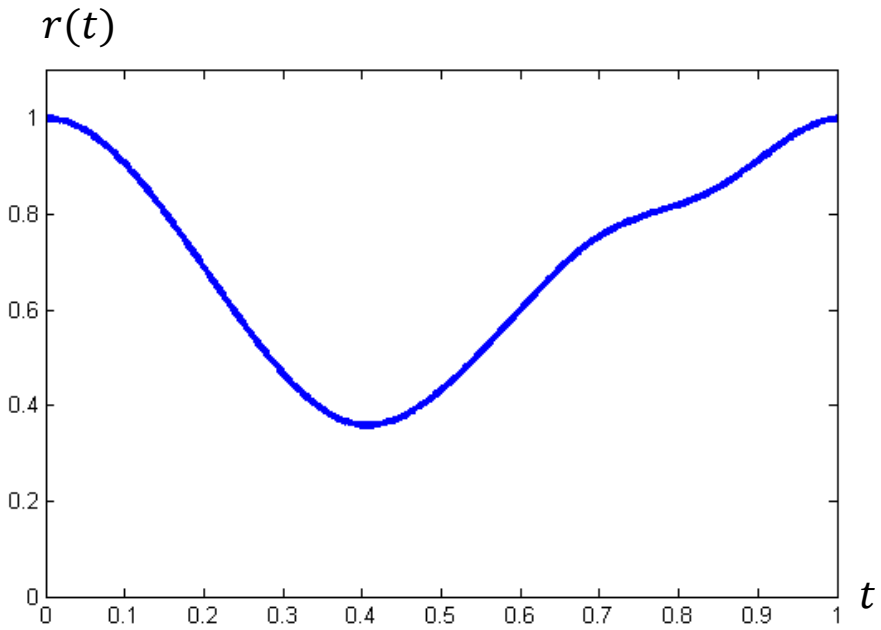


Splines cubiques



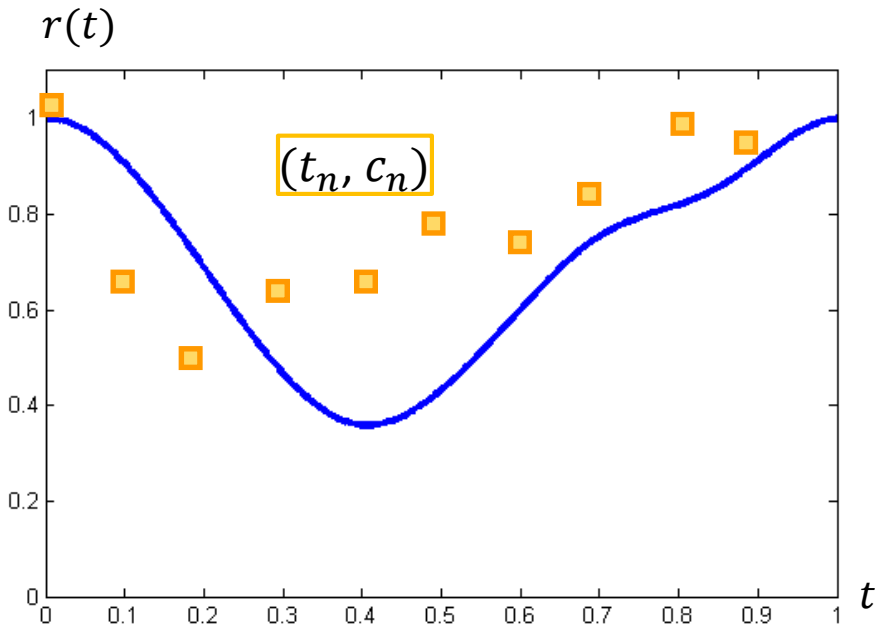
Ventriculographie isotopique

COURBE de REFERENCE



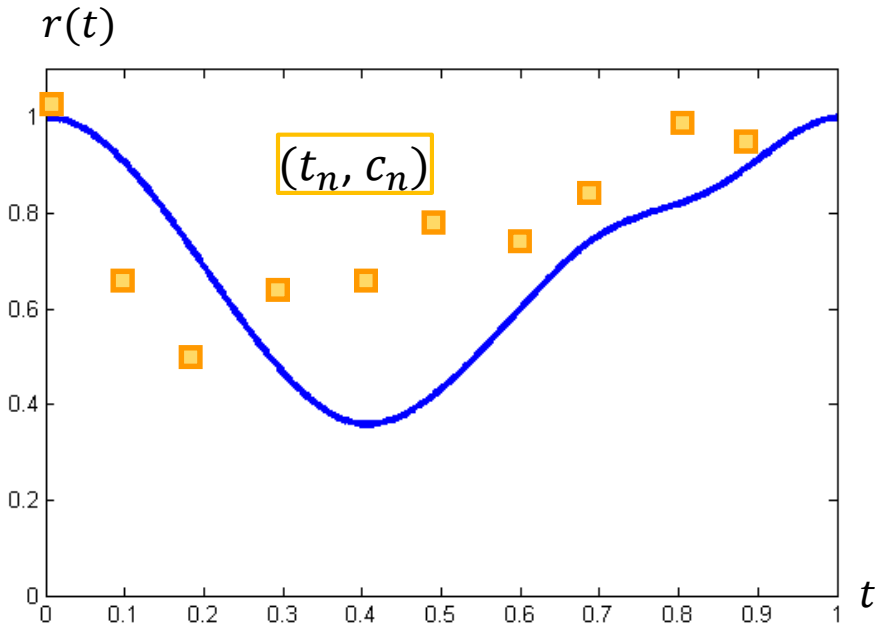
Ventriculographie isotopique

COURBE de REFERENCE



Ventriculographie isotopique

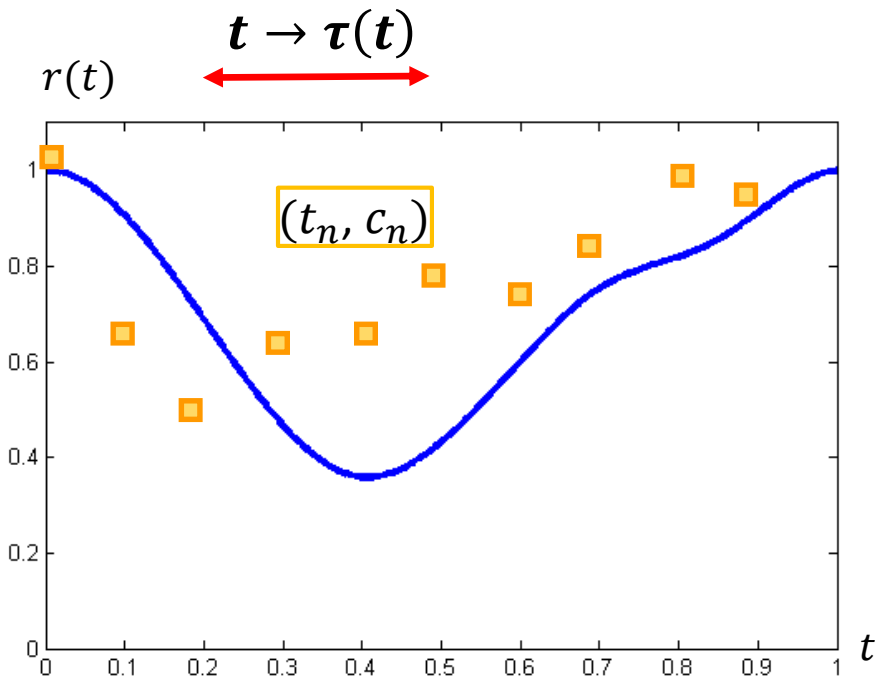
COURBE de REFERENCE



$$r(.) \rightarrow \eta[r(.)]$$

Ventriculographie isotopique

COURBE de REFERENCE



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Ventriculographie isotopique

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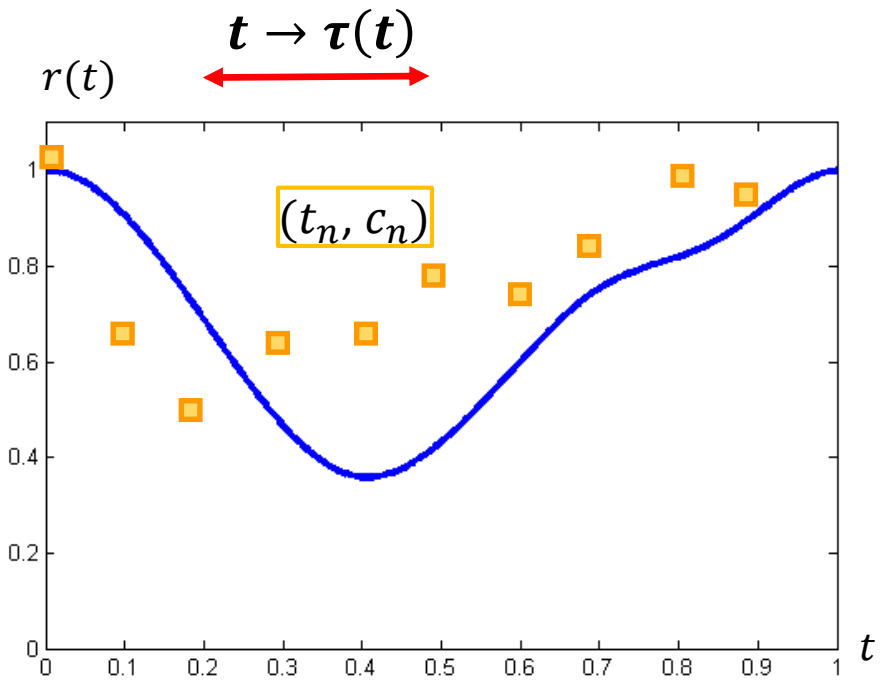

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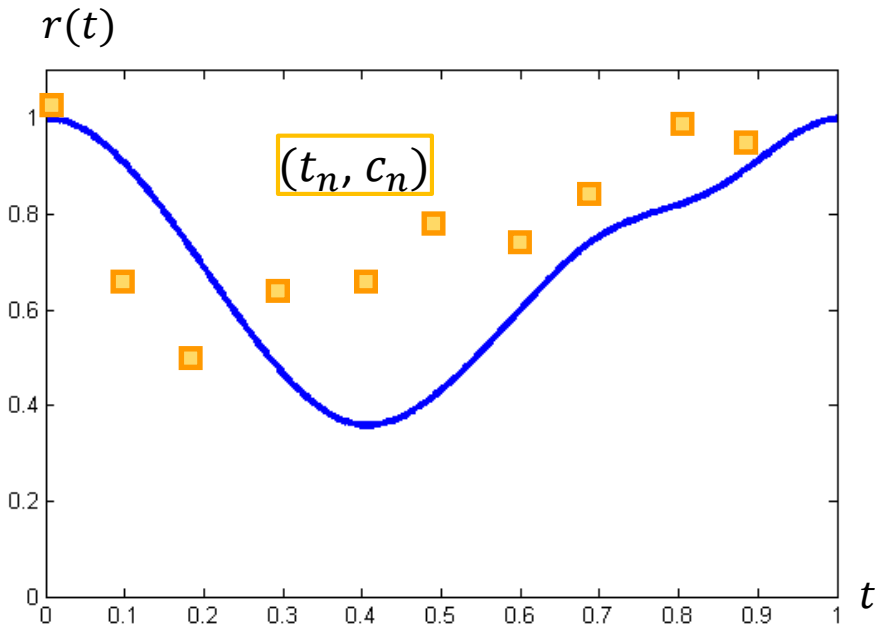

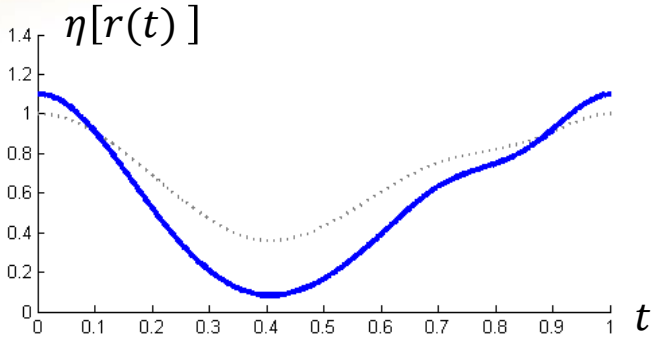

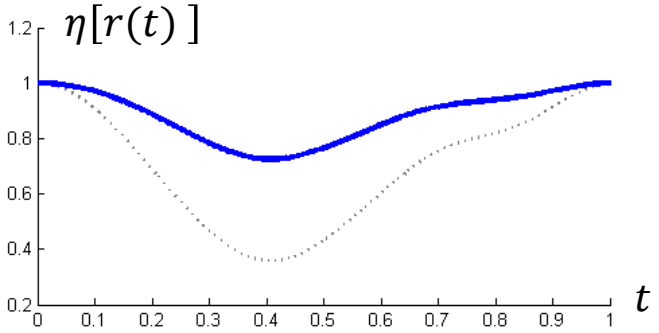

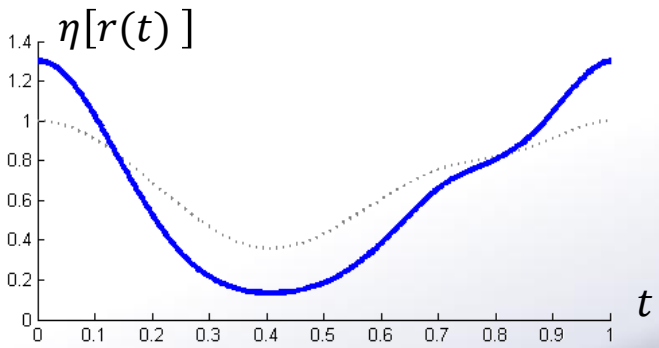

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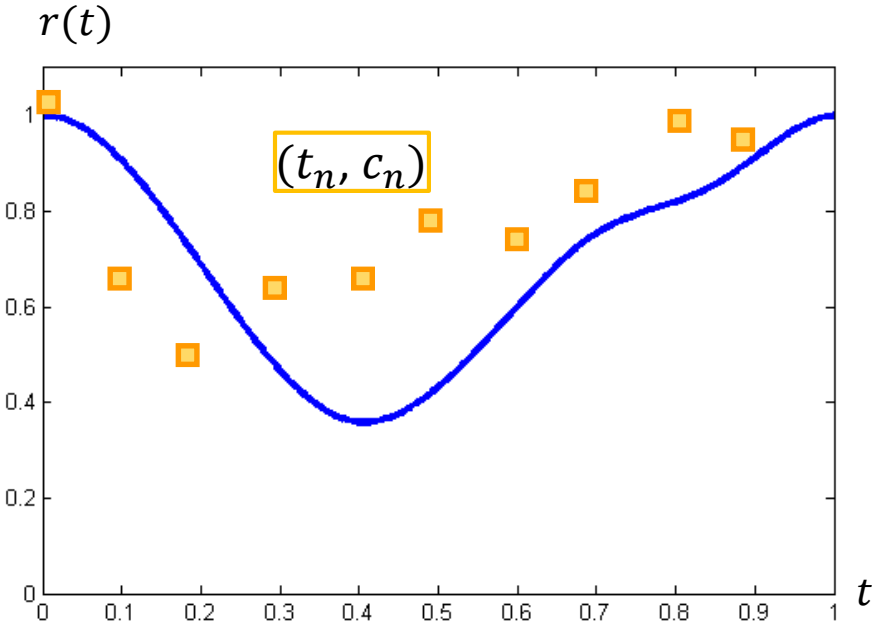

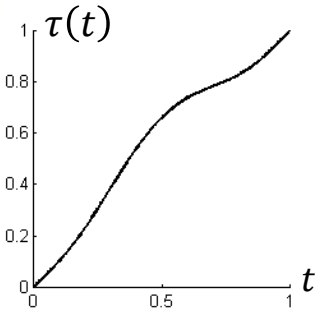

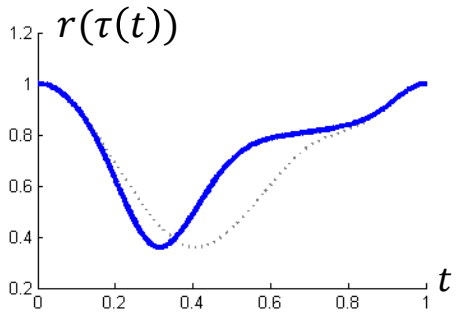

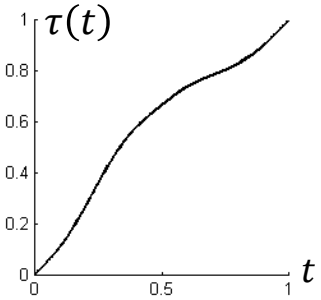

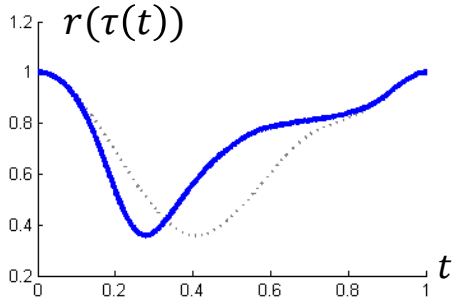

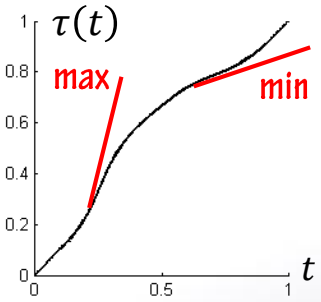

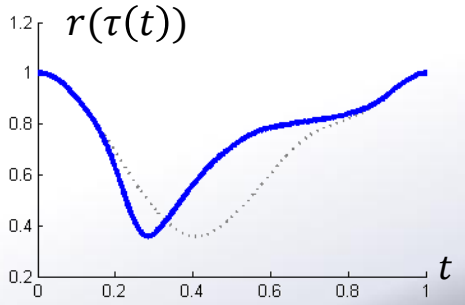

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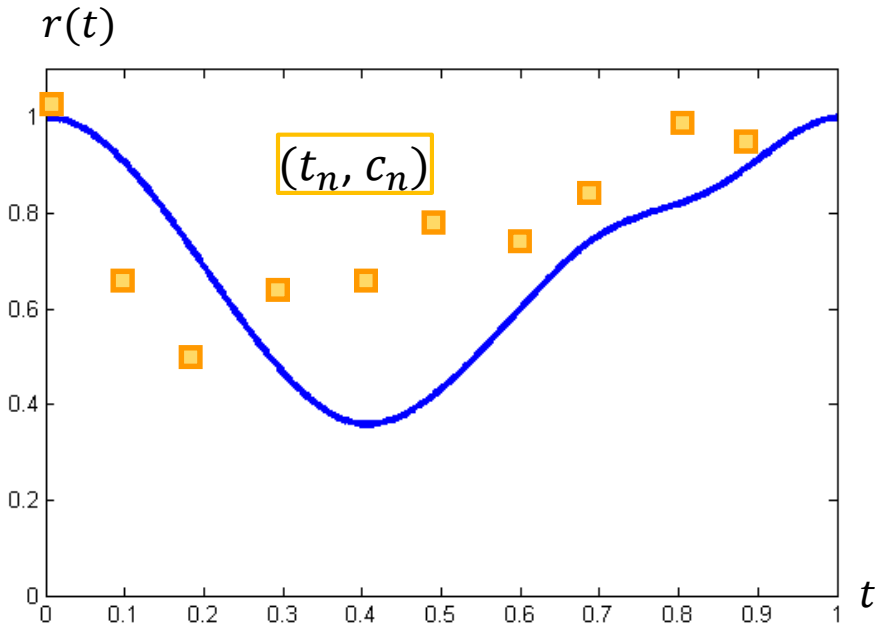

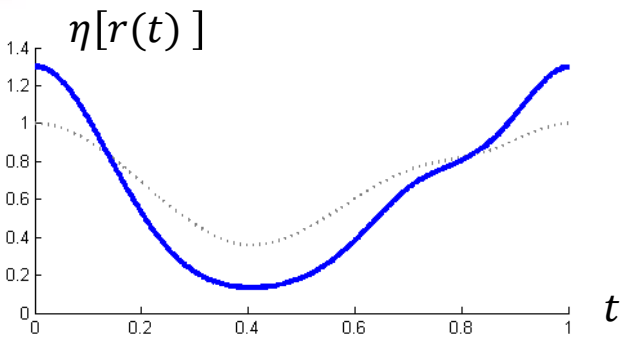

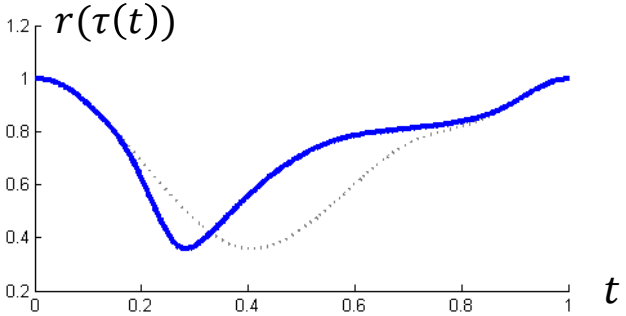

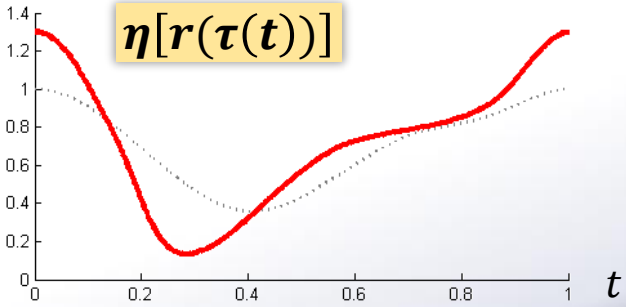

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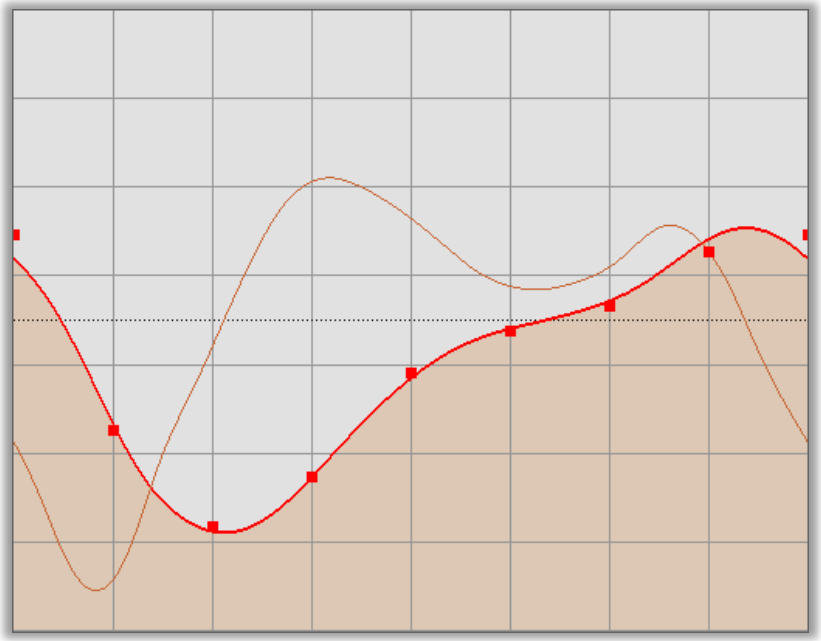
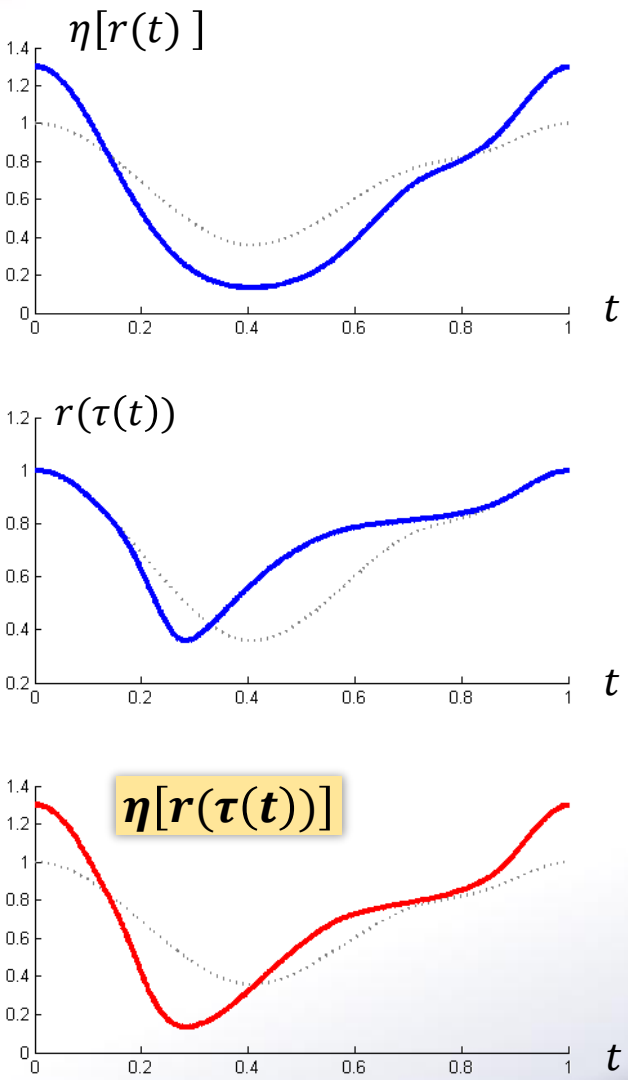
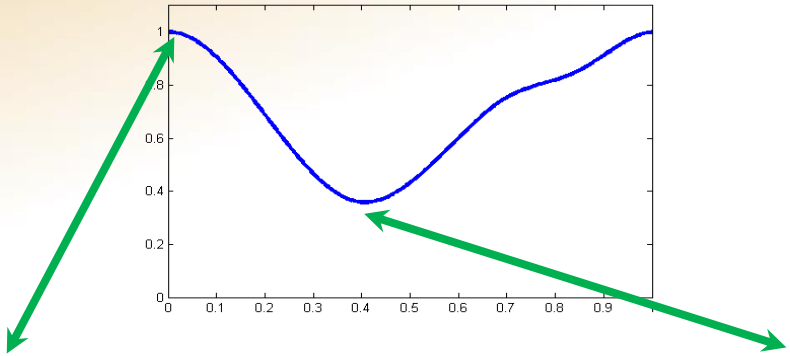
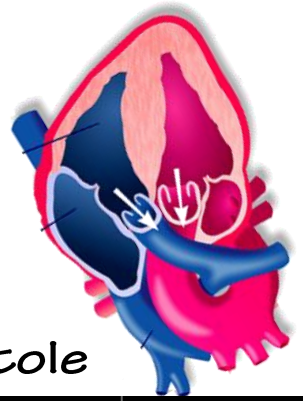




Tomo-ventriculographie

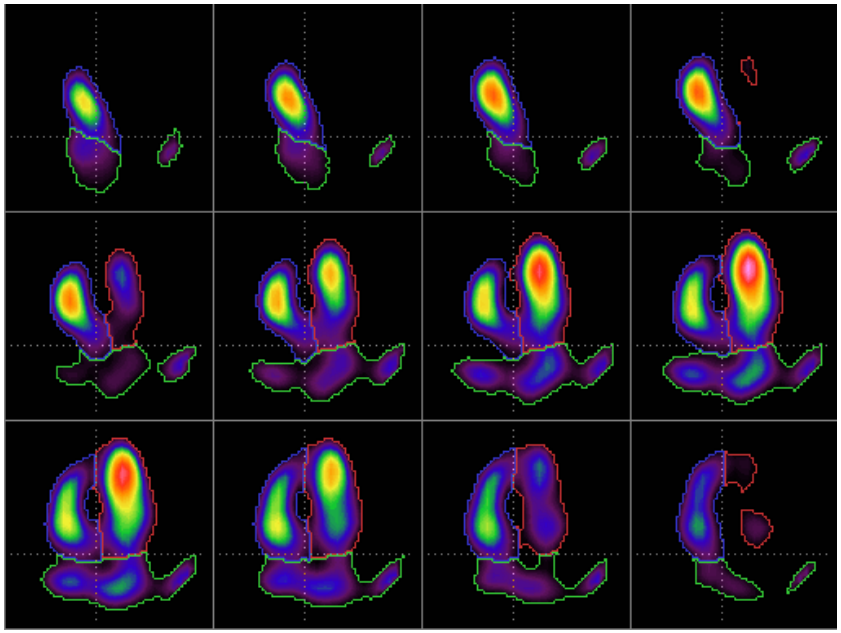
SEGMENTATION

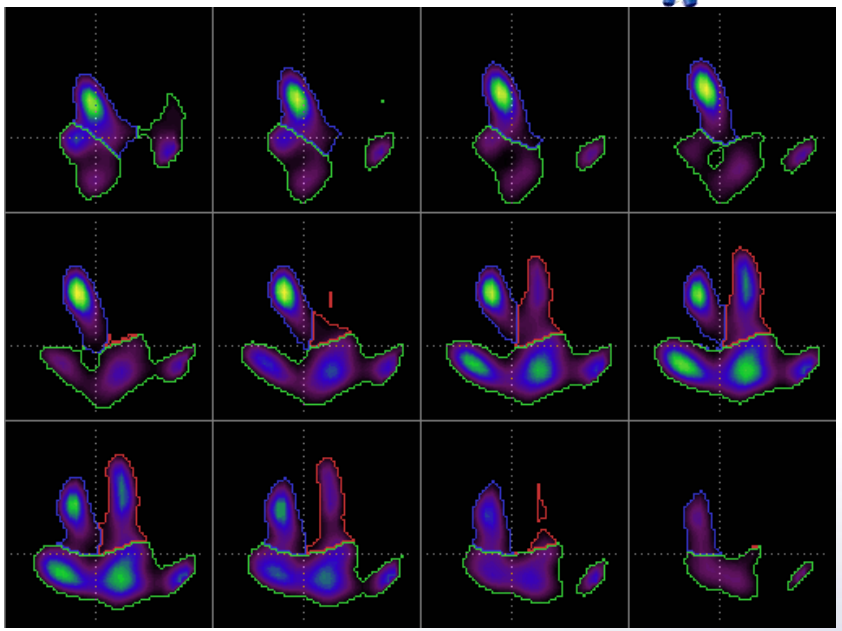




Fin de diastole

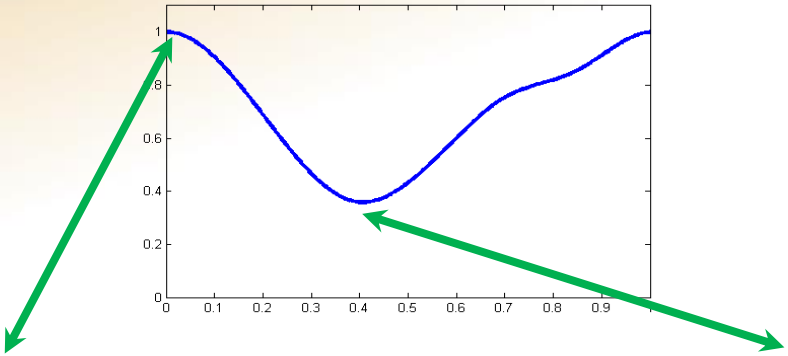
Fin de systole

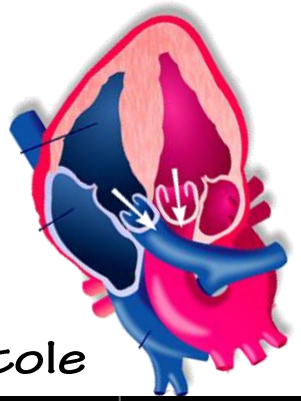




Tomo-ventriculographie

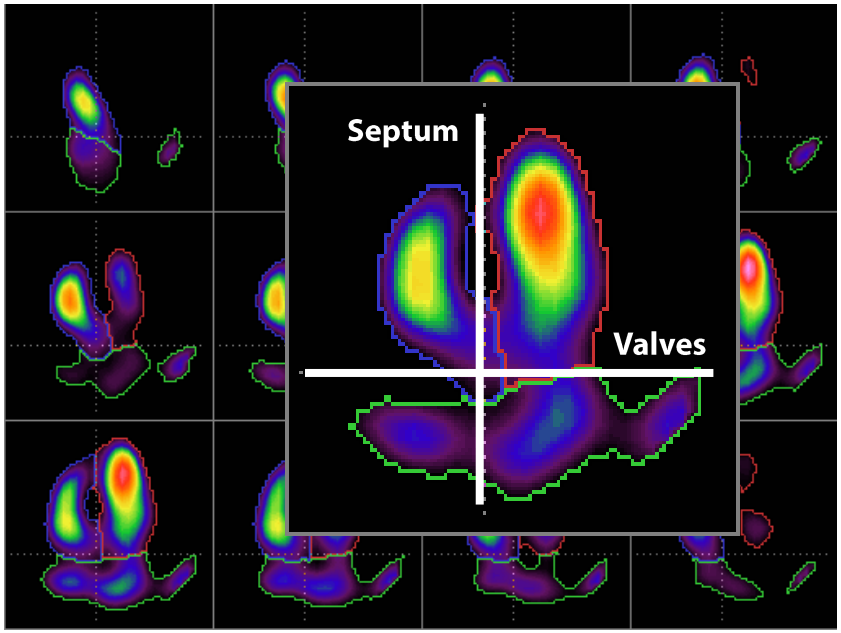
SEGMENTATION

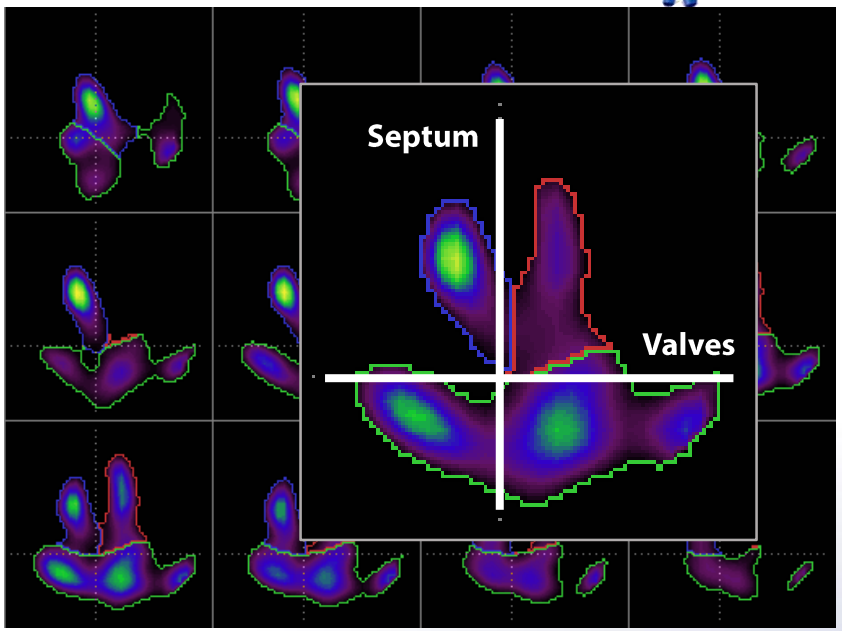




Fin de diastole

Fin de systole

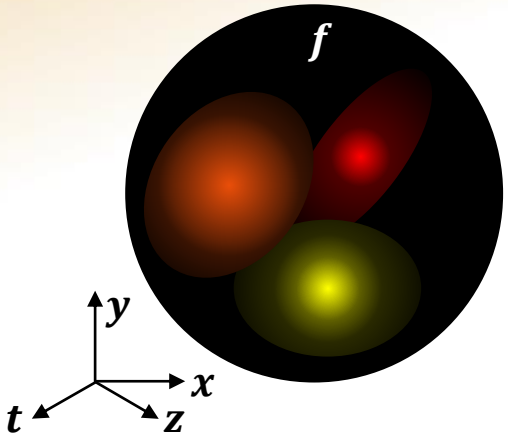


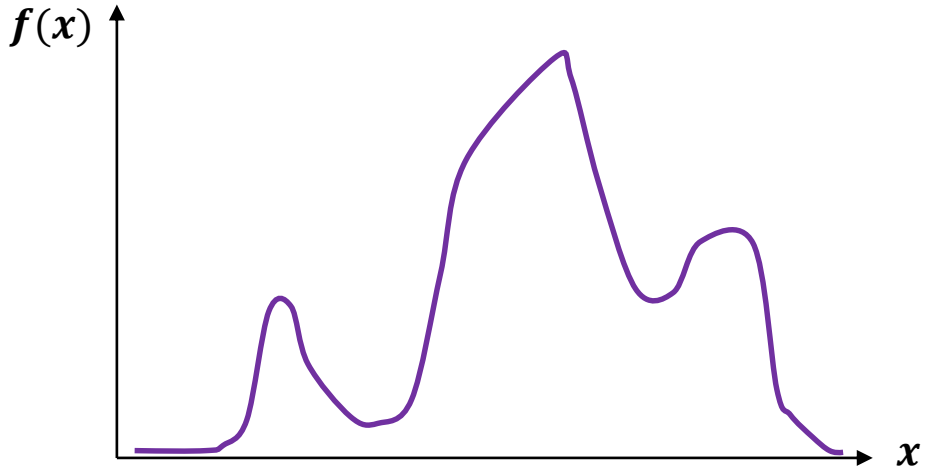


Tomo-ventriculographie

SEGMENTATION

Immersion / ligne de partage des eaux

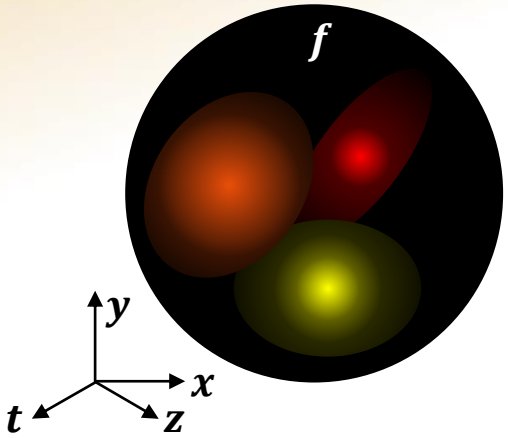


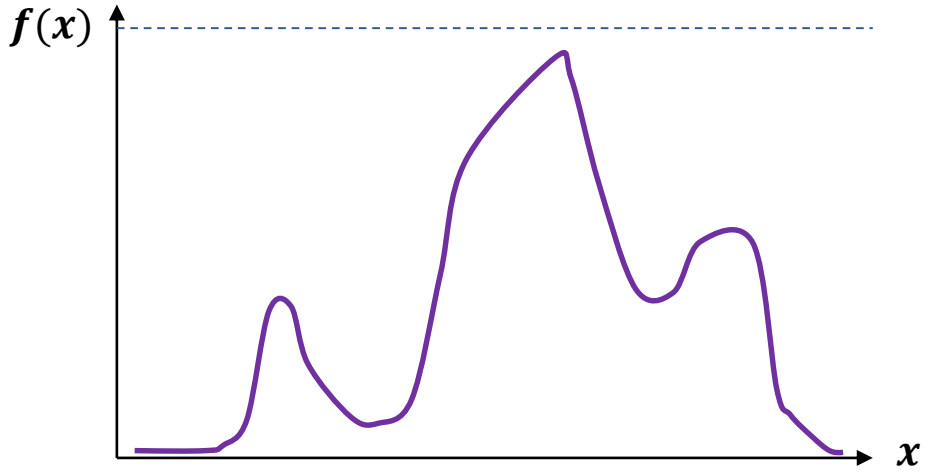


Tomo-ventriculographie

SEGMENTATION

Immersion / ligne de partage des eaux





Tomo-ventriculographie

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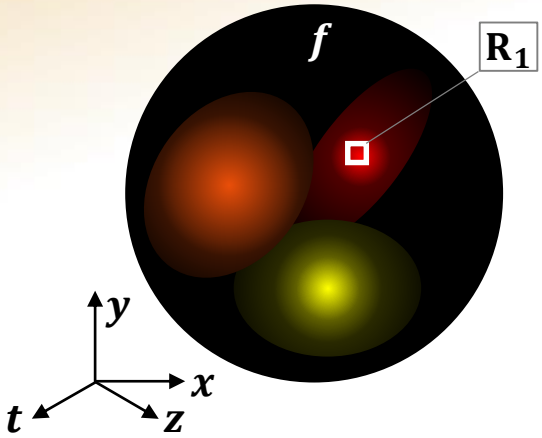
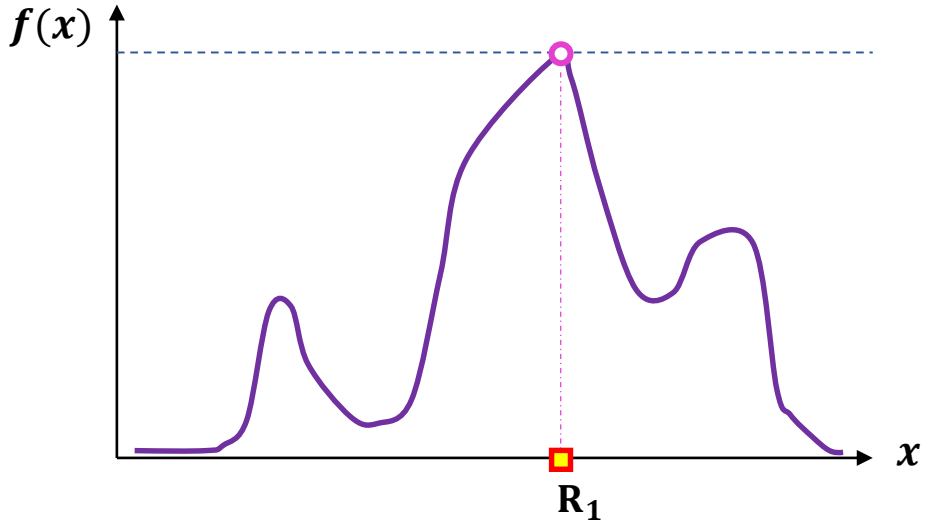
Immersion / ligne de partage des eaux





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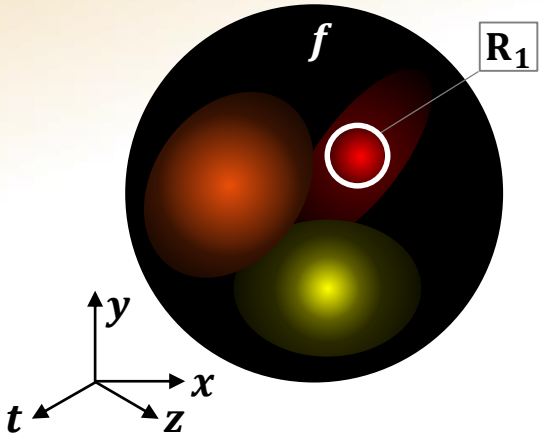

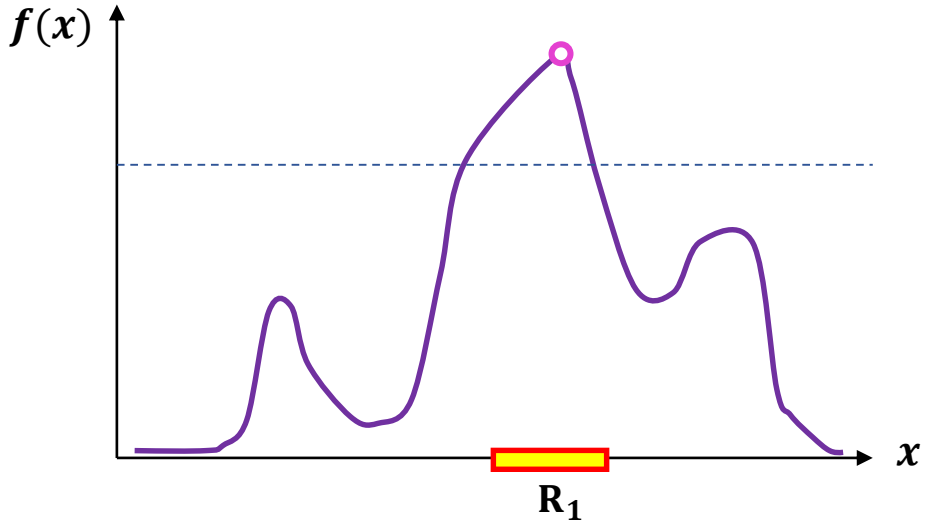

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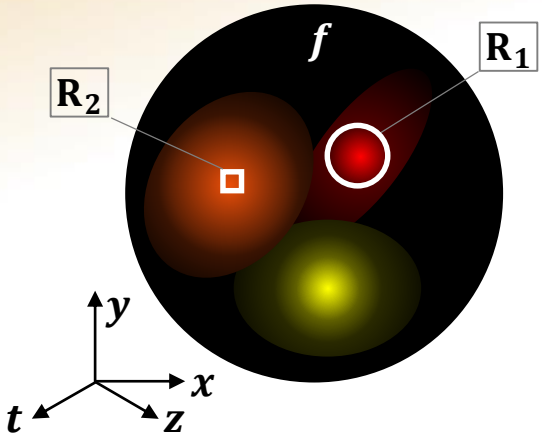

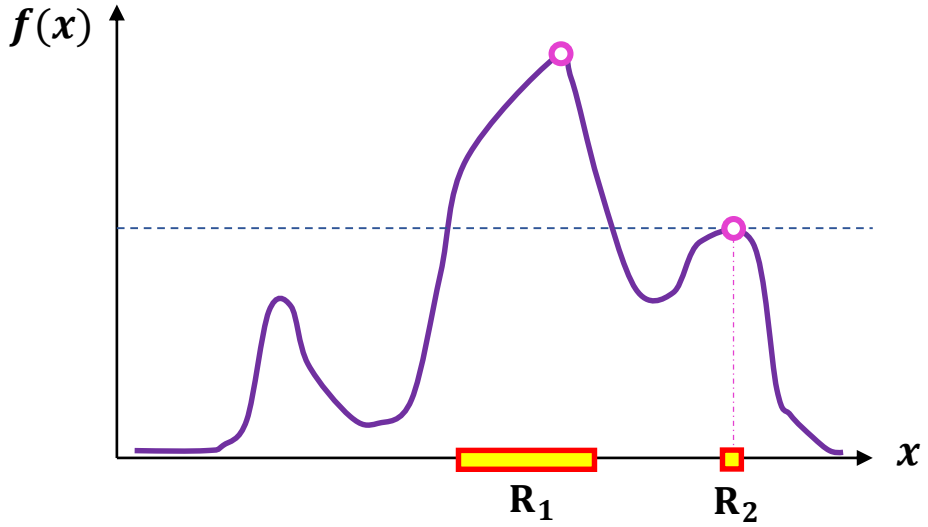

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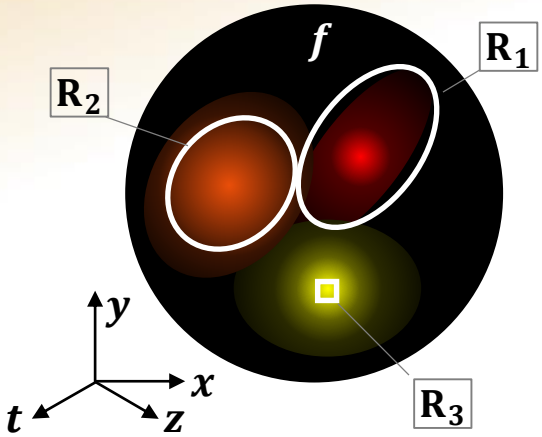

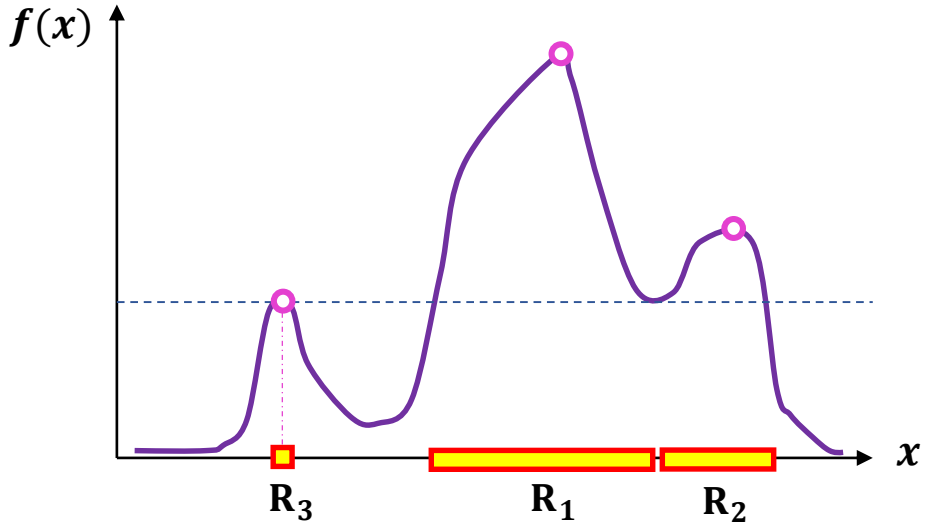

Tomo-ventriculographie

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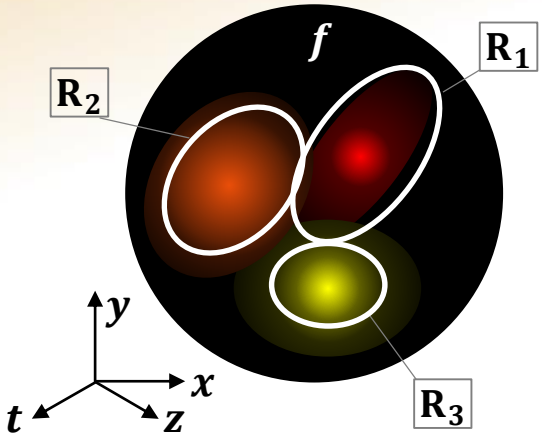

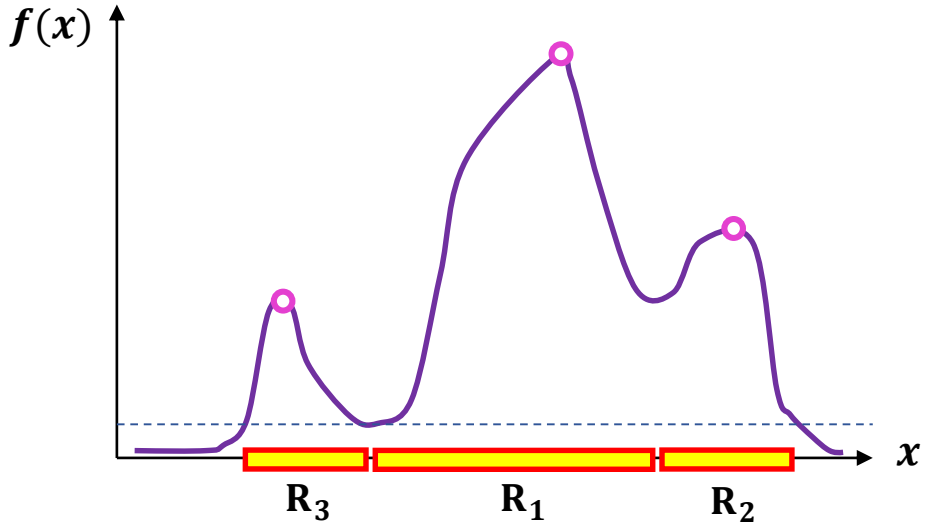

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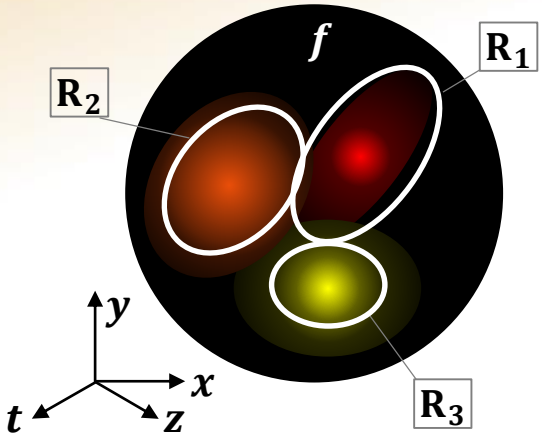

$$\Pi = \{\mathbf{R_1}, \mathbf{R_2}, \ldots, \mathbf{R_K}\}$$

$$\begin{cases} g_{k,x} = barycentre_x(\mathbf{R_k}) \\ g_{k,y} = barycentre_y(\mathbf{R_k}) \end{cases}$$

Tomo-ventriculographie

SEGMENTATION

Immersion / ligne de partage des eaux

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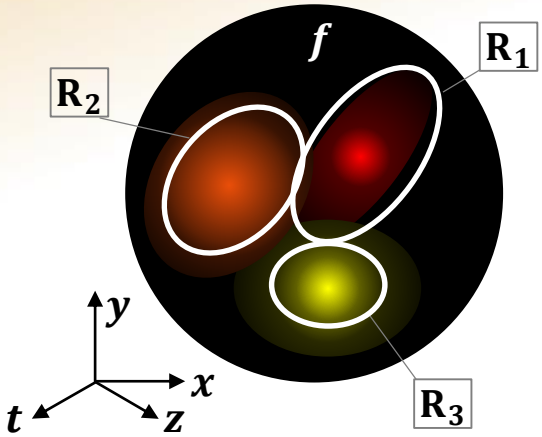
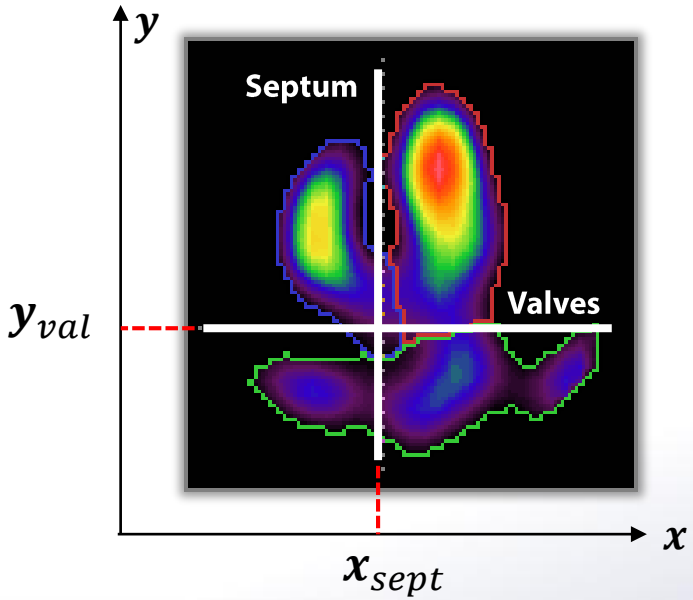


$g_{k,y} < y_{val}$

$R_k \subset$ ATRIA



Tomo-ventriculographie

SEGMENTATION

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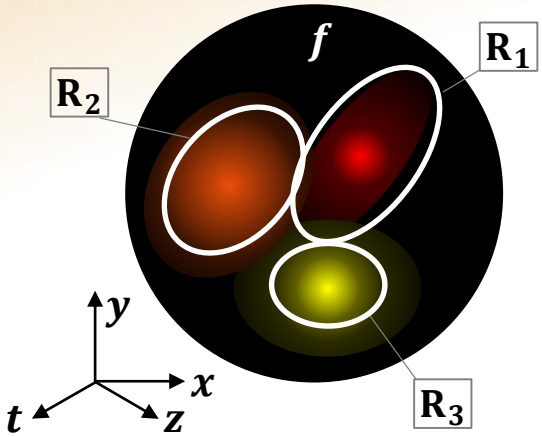


$g_{k,y} < y_{val}$

$R_k \subset$ ATRIA

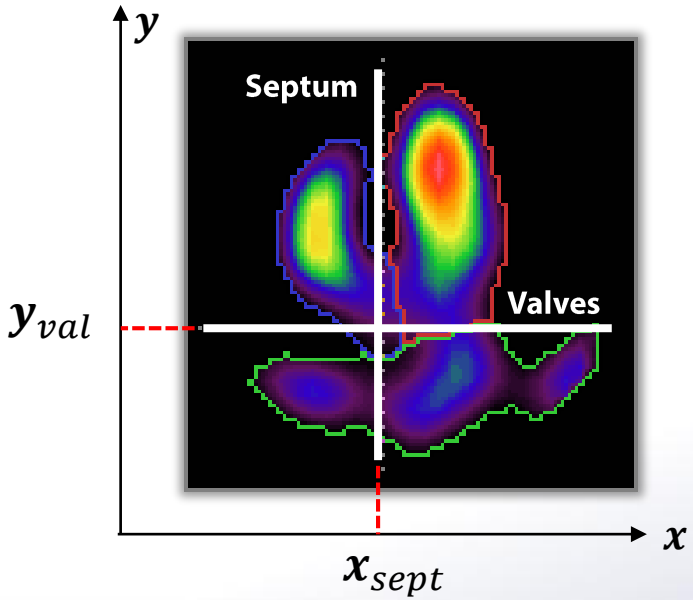
$g_{k,y} \geq y_{val}$

$g_{k,y} < x_{sept}$

$R_k \subset$ VD

$g_{k,y} \geq x_{sept}$

$R_k \subset$ VG



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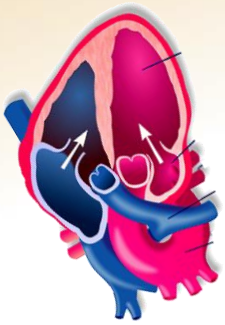
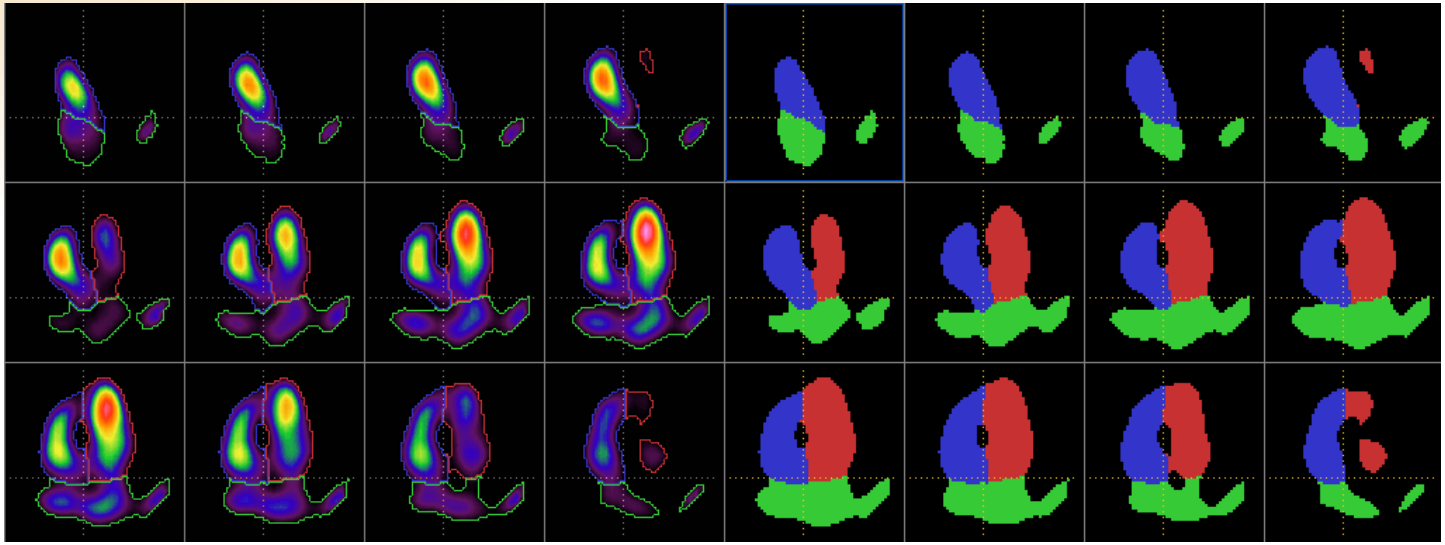
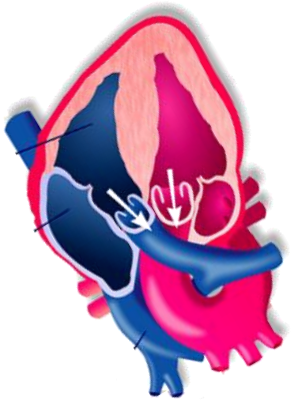
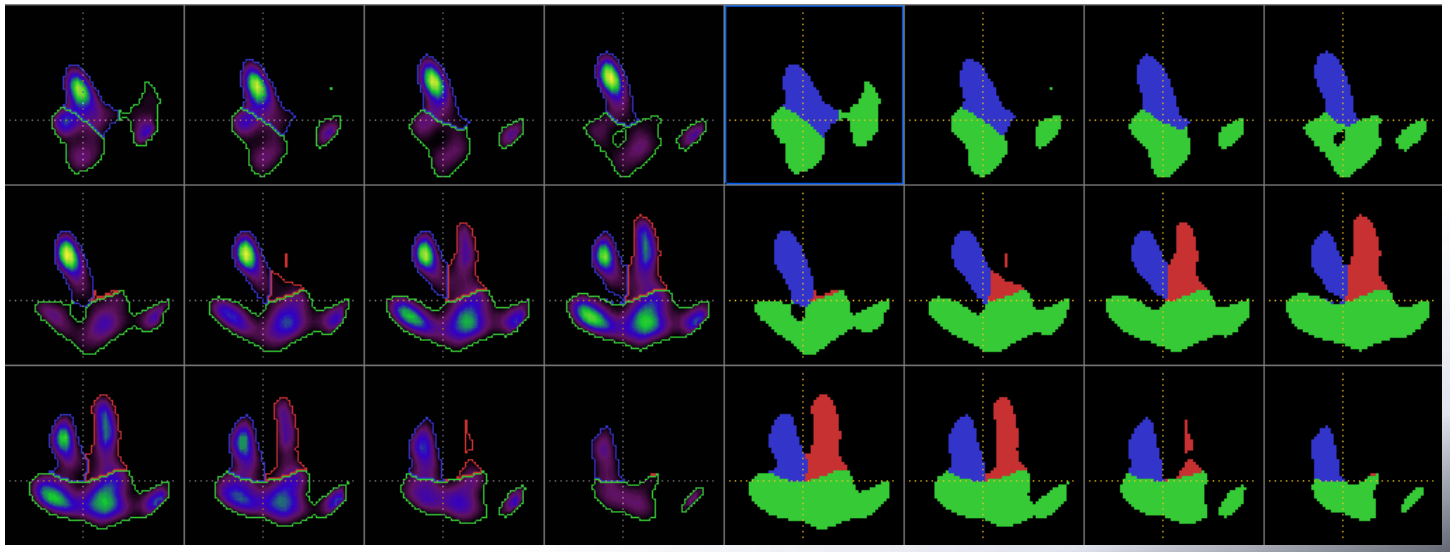


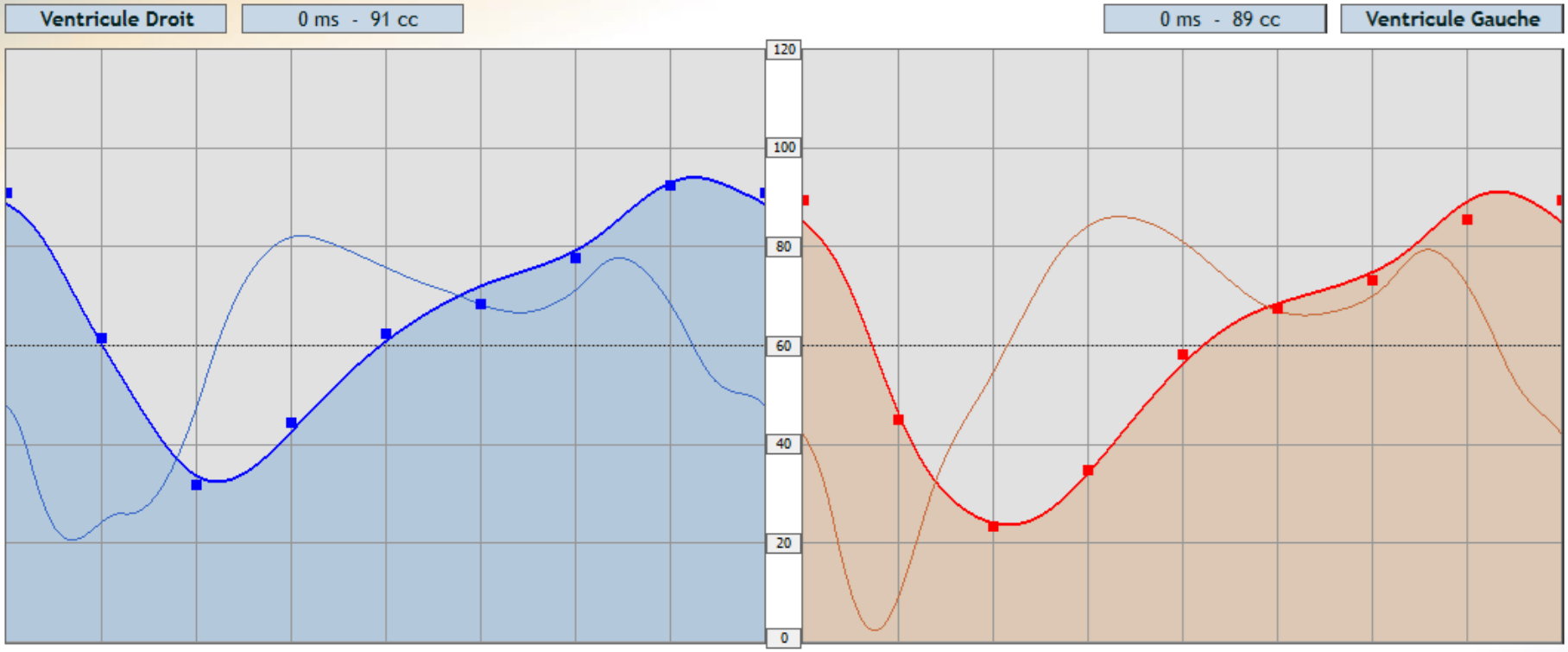






Tomo-ventriculographie

CINETIQUE GLOBALE



Volume télédiastolique = 94 cc
Volume télésystolique = 32 cc
Volume d'éjection = 62 cc - Débit = 3.1 L / min

Fraction d'éjection = 66 %
Temps de fin de systole : 328 ms

Débit eject. max. = -245 cc/s (-2.62) - t-DEM = 103 ms
Débit remp. max. = 139 cc/s (1.48) - t-DRM = 459 ms

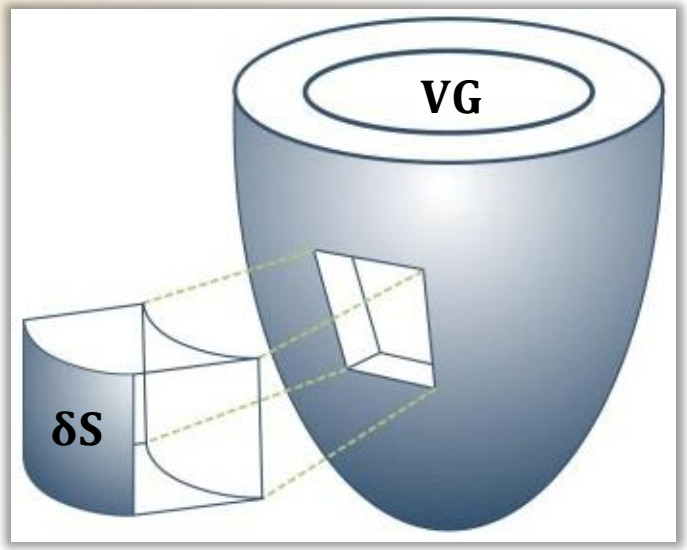
Volume télédiastolique = 91 cc
Volume télésystolique = 24 cc
Volume d'éjection = 67 cc - Débit = 3.4 L / min

Fraction d'éjection = 74 %
Temps de fin de systole : 317 ms

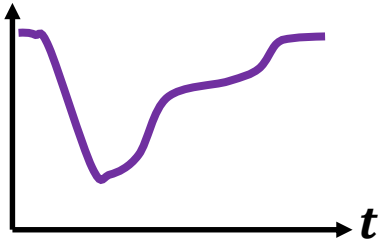
Débit eject. max. = -349 cc/s (-3.84) - t-DEM = 110 ms
Débit remp. max. = 158 cc/s (1.74) - t-DRM = 489 ms

Tomo-ventriculographie

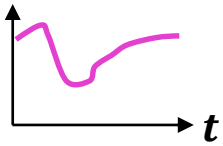
CINETIQUE LOCALE



$f_{VG}(t)$

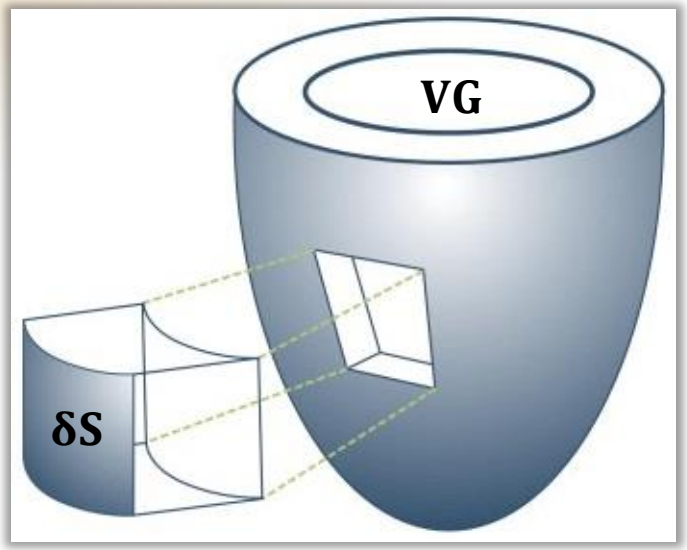


$f_{\delta S}(t)$

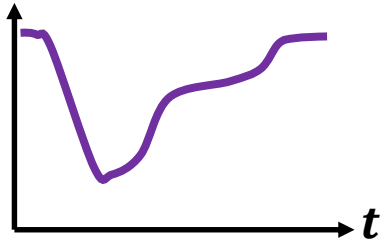


Tomo-ventriculographie

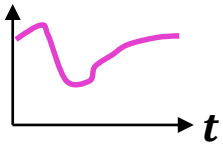
CINETIQUE LOCALE



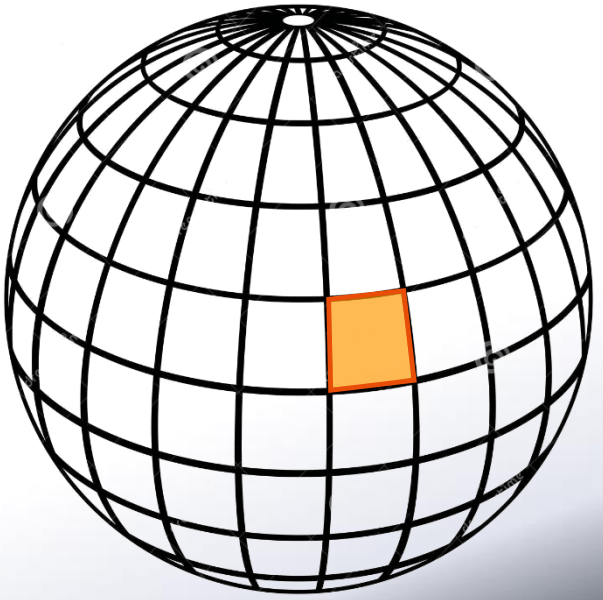
$f_{VG}(t)$



$f_{\delta S}(t)$

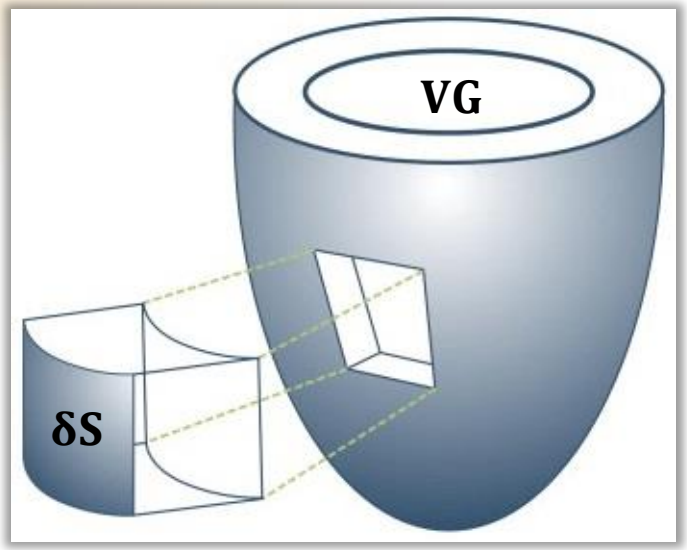


$\delta S(\theta_i , \varphi_j)$

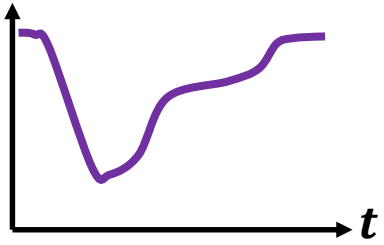


Tomo-ventriculographie

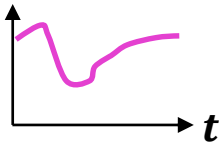
CINETIQUE LOCALE



$f_{VG}(t)$

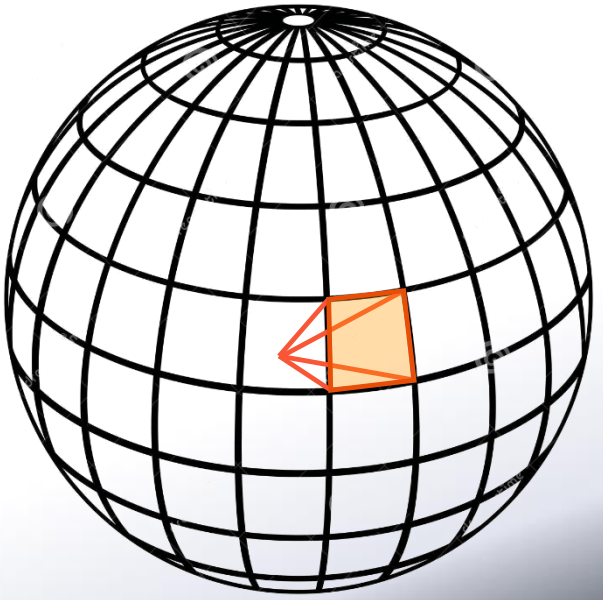


$f_{\delta V}(t)$



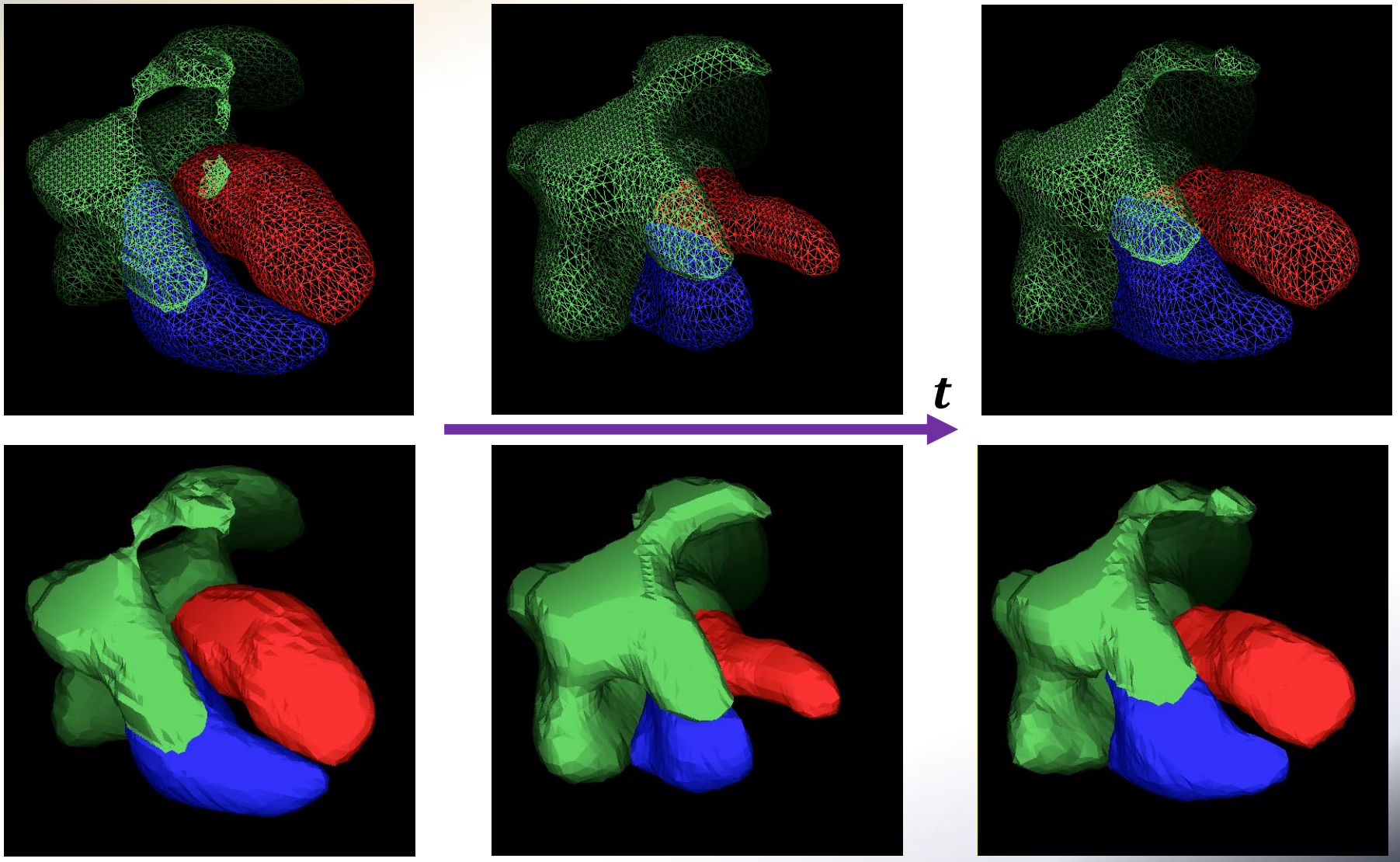
$\delta S(\theta_i , \varphi_j)$

$\delta V(\theta_i , \varphi_j)$



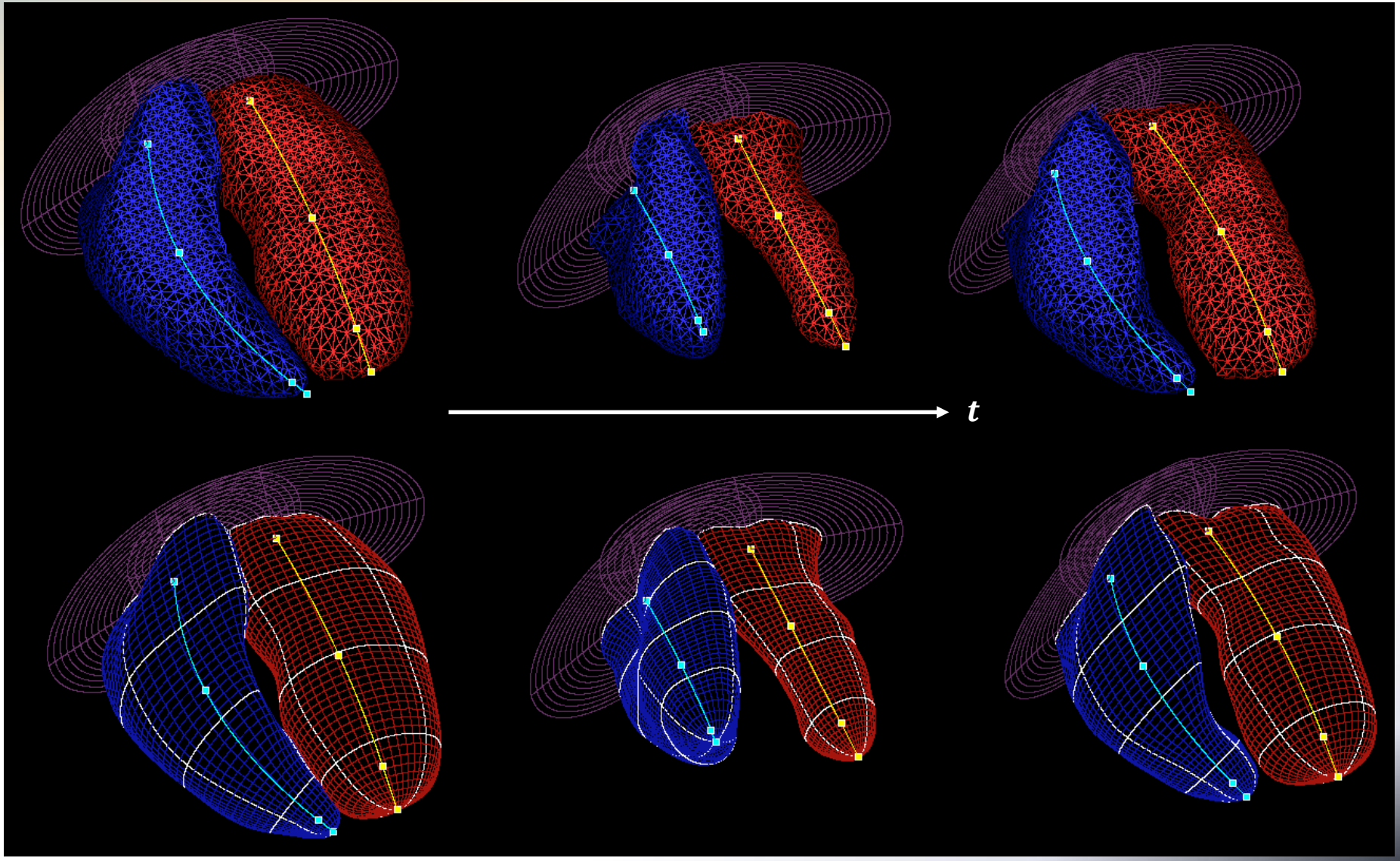
Tomo-ventriculographie

PARAMETRISATION 3D



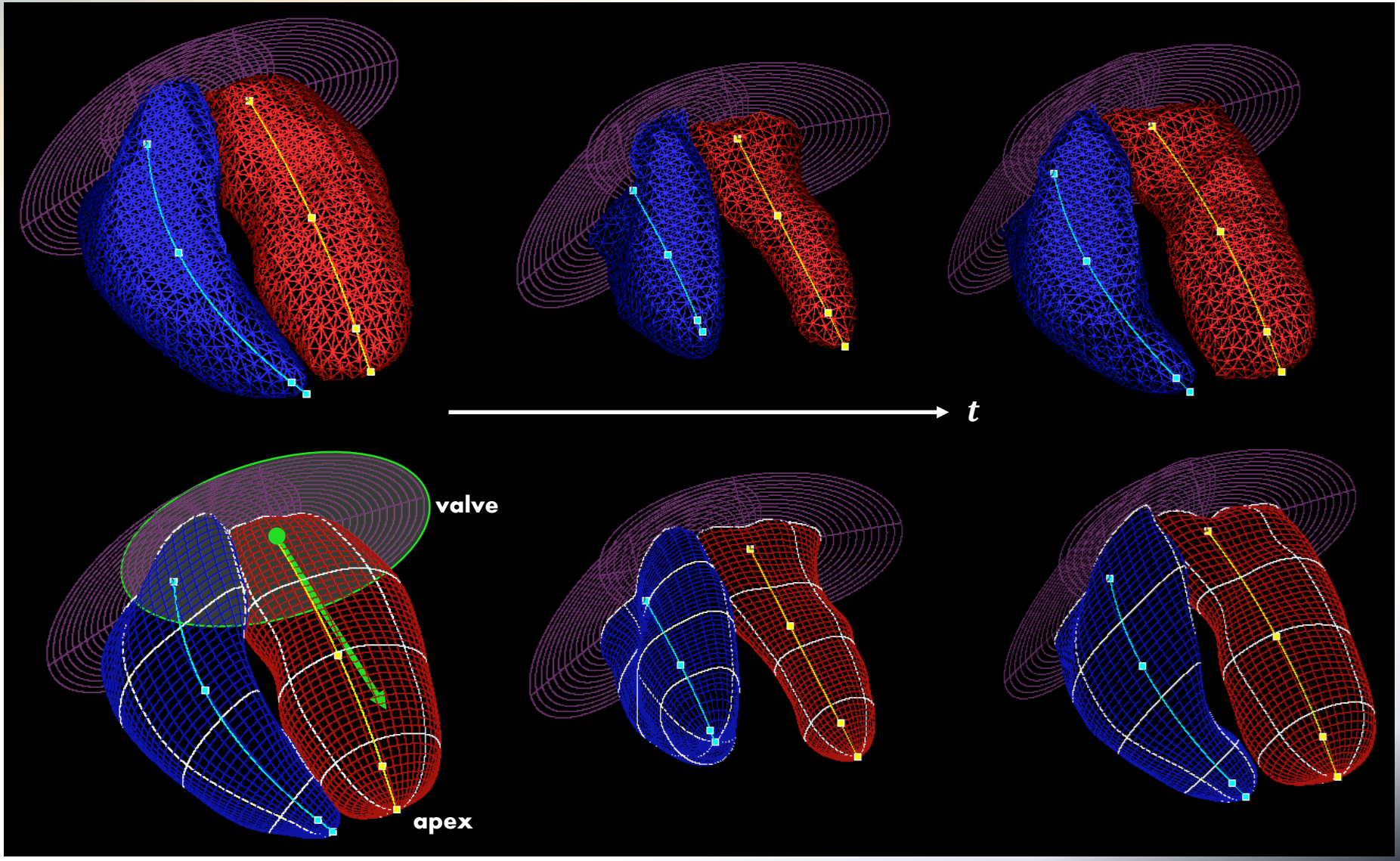
Tomo-ventriculographie

PARAMETRISATION 3D



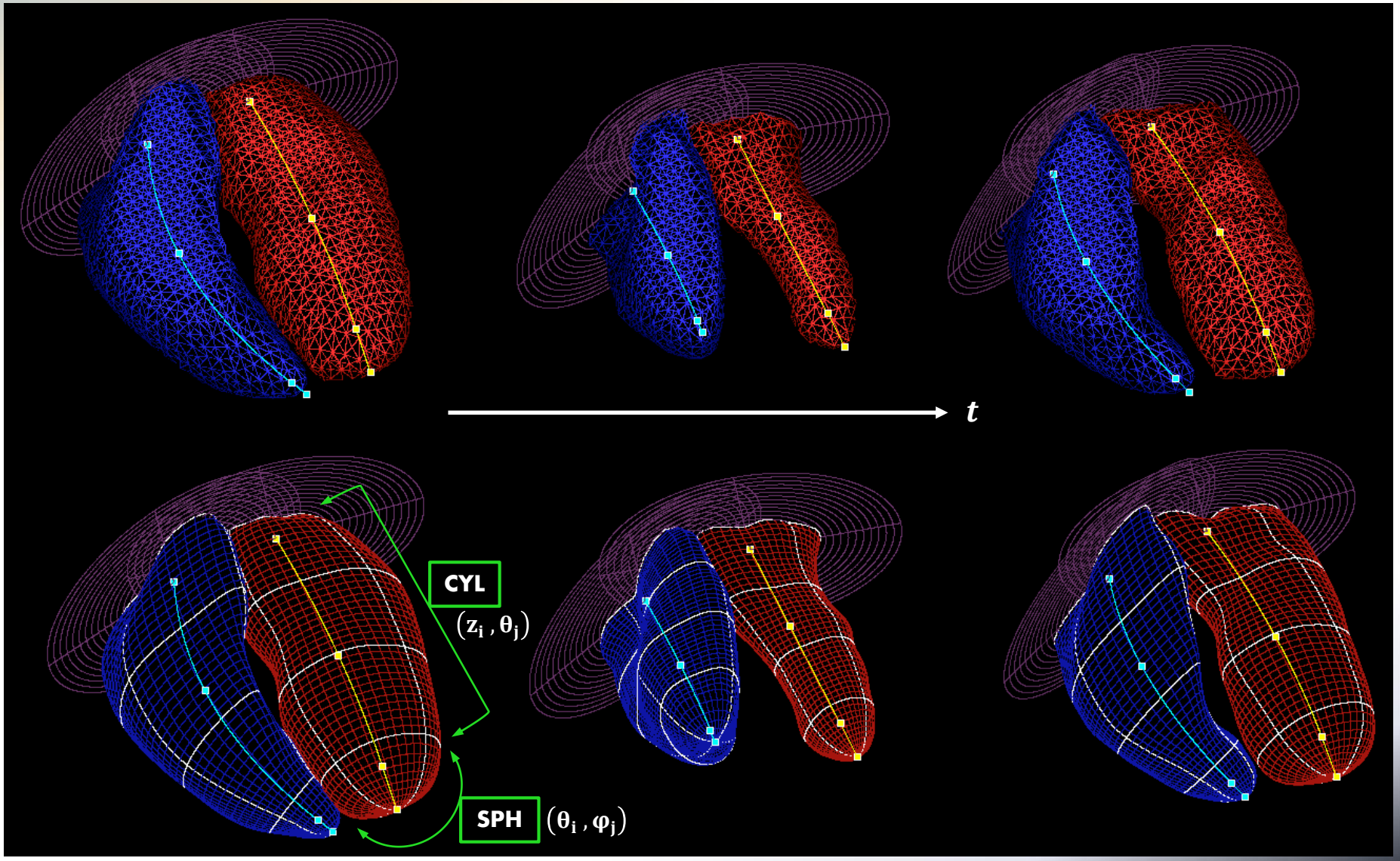
Tomo-ventriculographie

PARAMETRISATION 3D



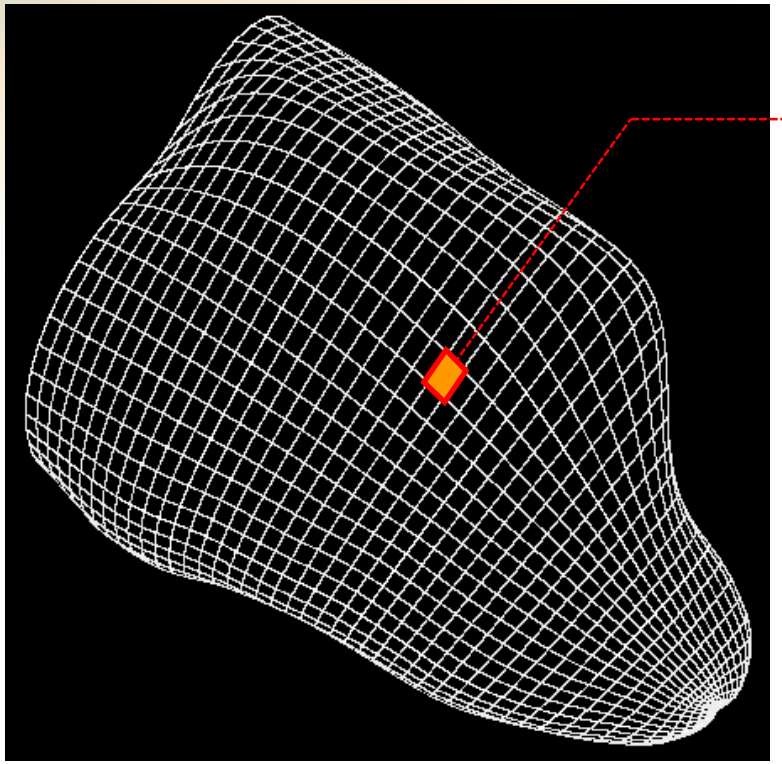
Tomo-ventriculographie

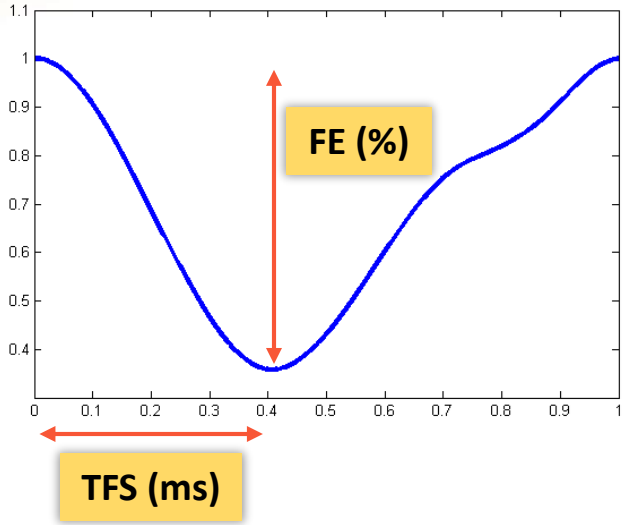
PARAMETRISATION 3D



Tomo-ventriculographie

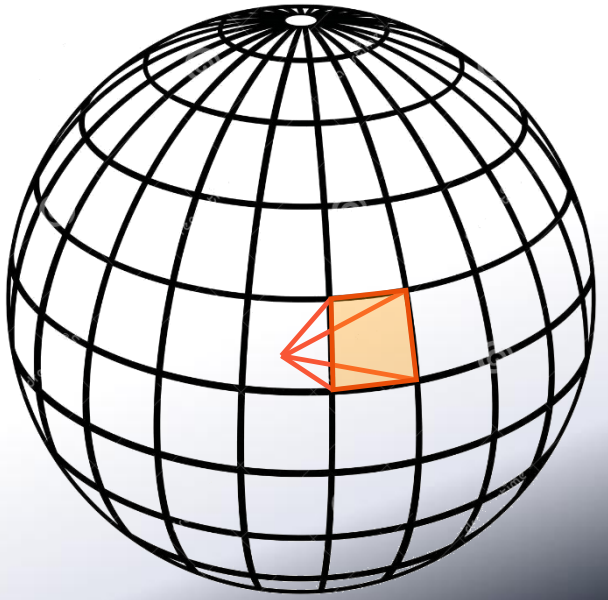
CINETIQUE LOCALE





$$\delta V(z_i , \theta_i)$$

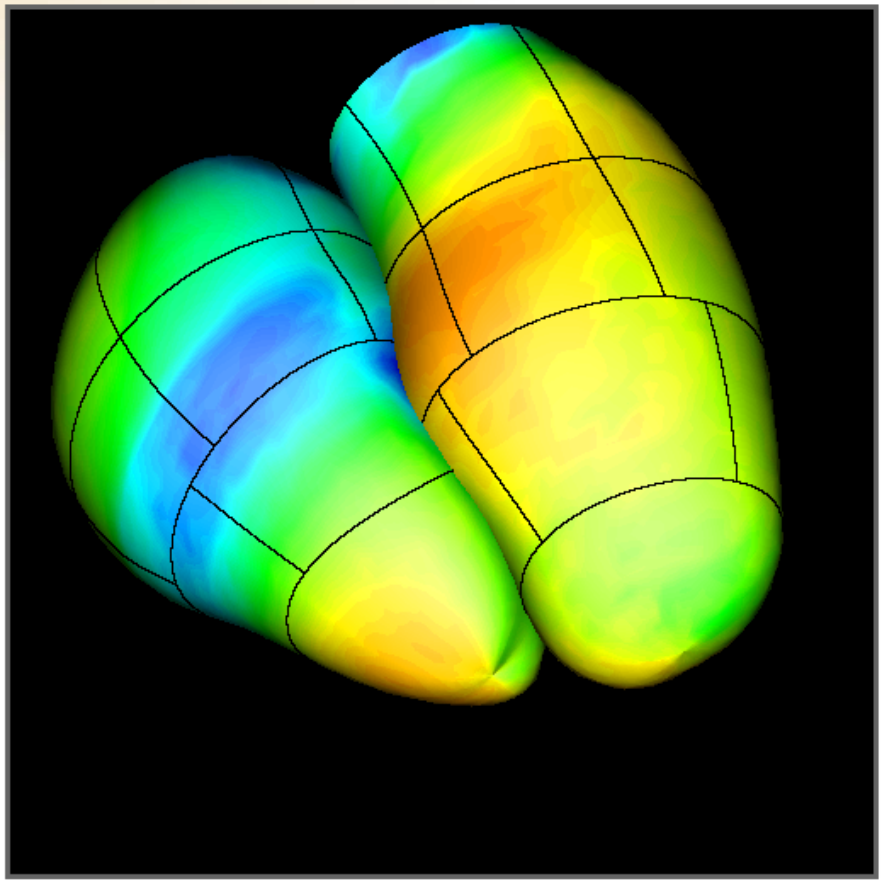
$$\delta V(\theta_i , \varphi_j)$$



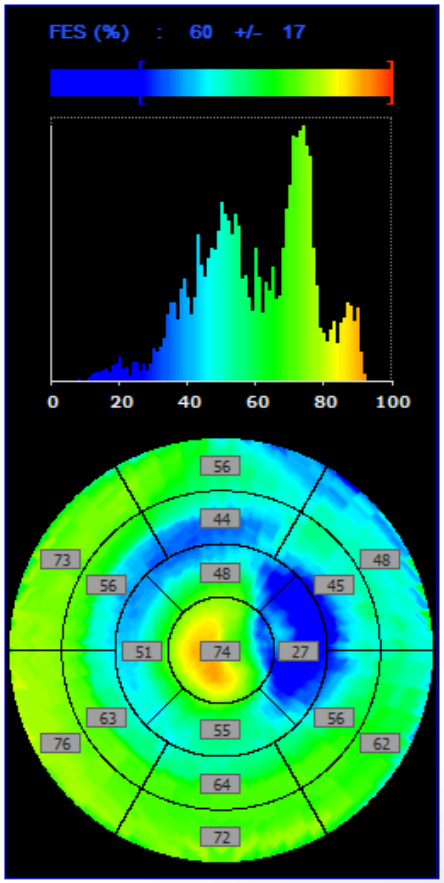
Tomo-ventriculographie

CINETIQUE LOCALE

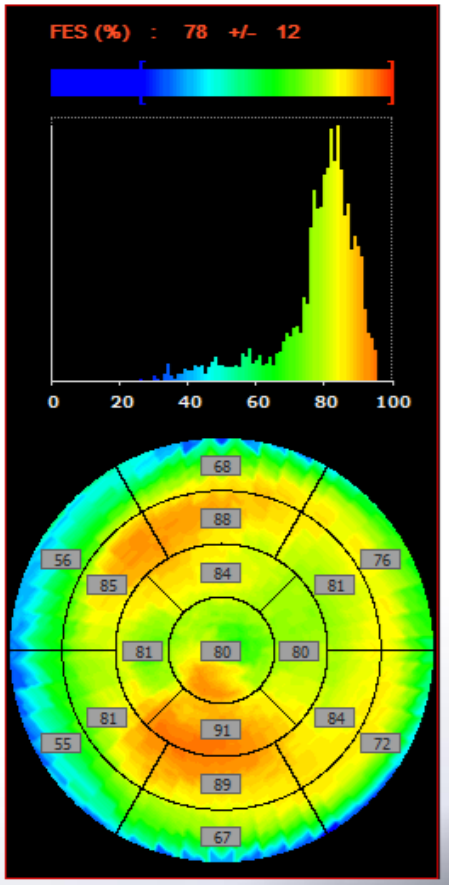
Fraction d'éjection systolique (%)



Vent. droit



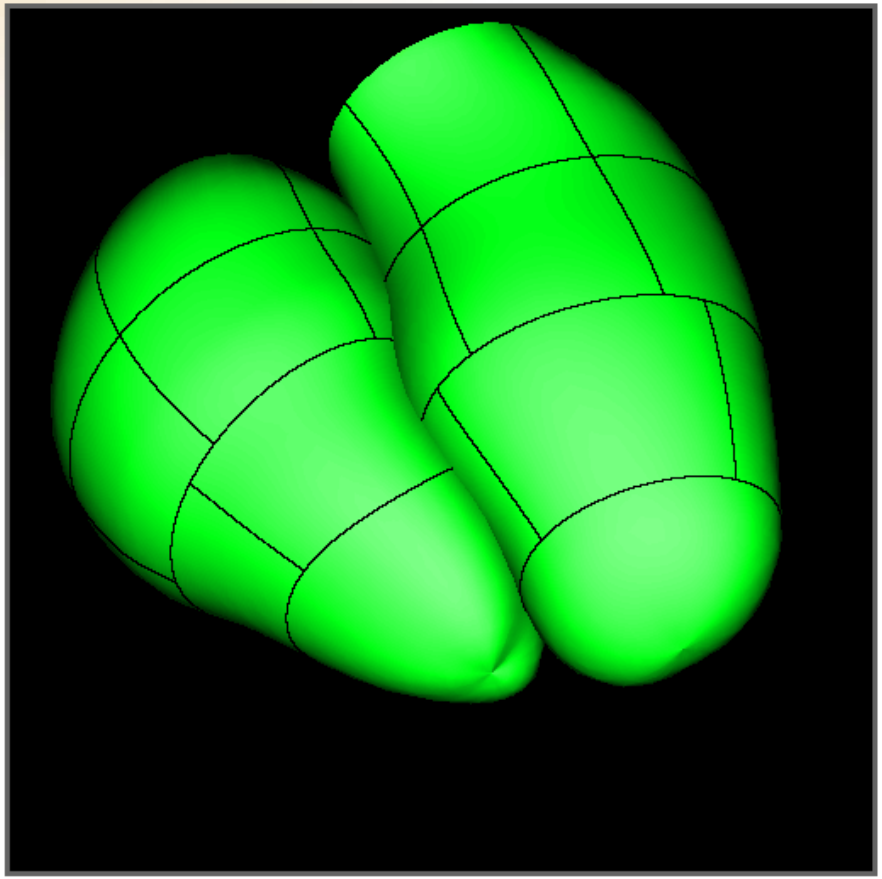
Vent. gauche



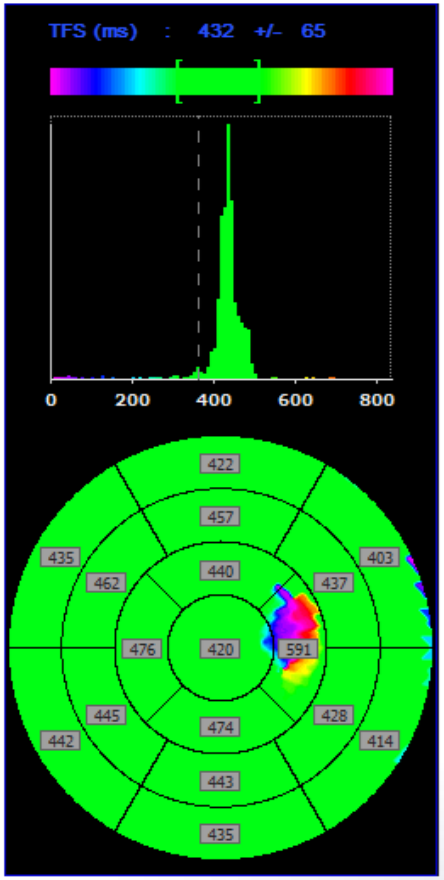
Tomo-ventriculographie

CINETIQUE LOCALE

Temps de fin de systole (ms)



Vent. droit



Vent. gauche