

# Imagerie de la perfusion tissulaire: en IRM dynamique par DCE-MRI

Charles A Cuenod

LRI-U970 Paris Descartes  
Parcc Hôpital G Pompidou, Paris

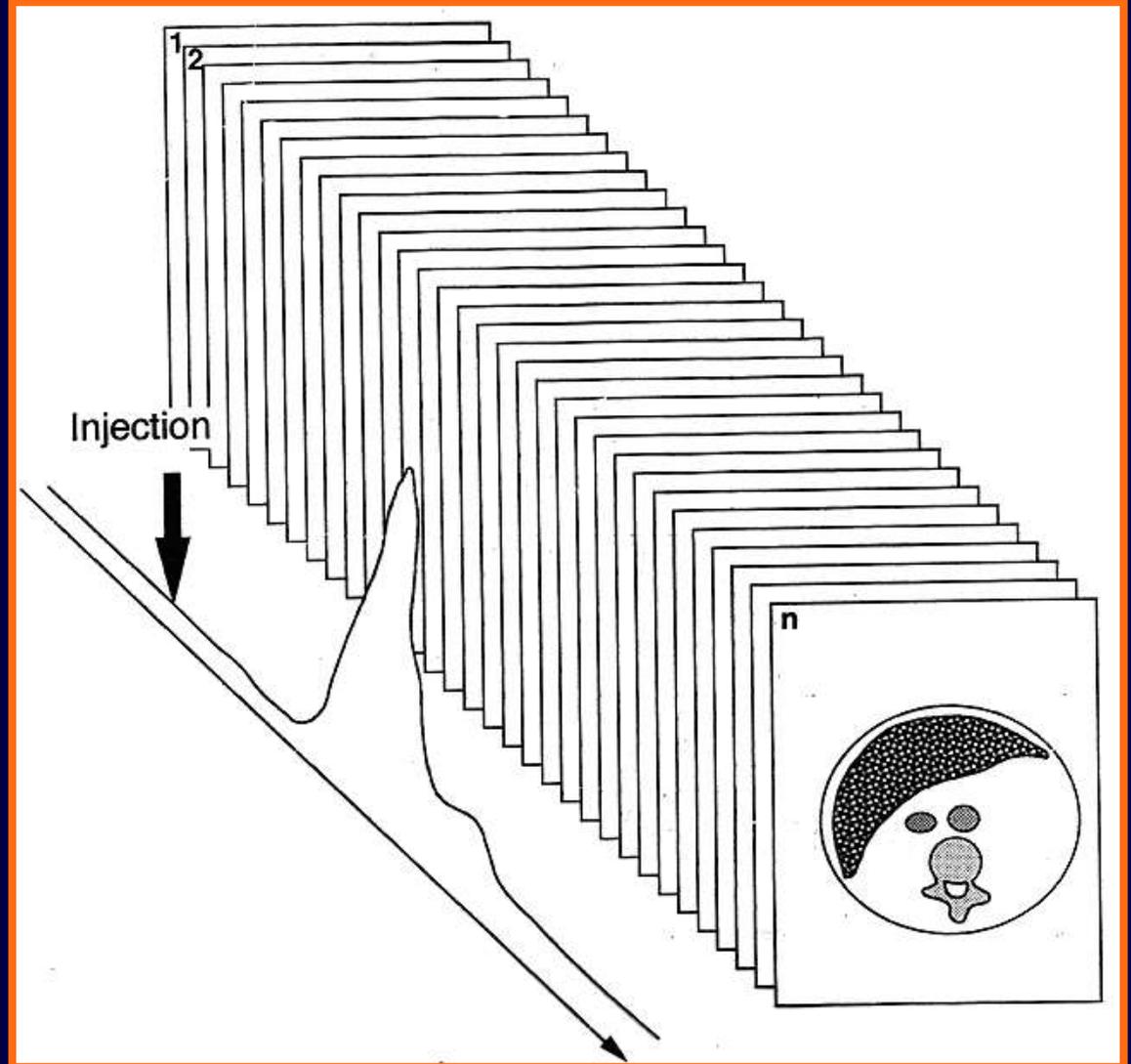
[Ca@cuenod.net](mailto:Ca@cuenod.net)

# Dynamic Contrast Enhanced MRI

## DCE-MRI

Injection PdC

Acquisition en pondération T1



# IRM dynamique de perfusion avec bolus de chélate de Gd

## Pondéré T1

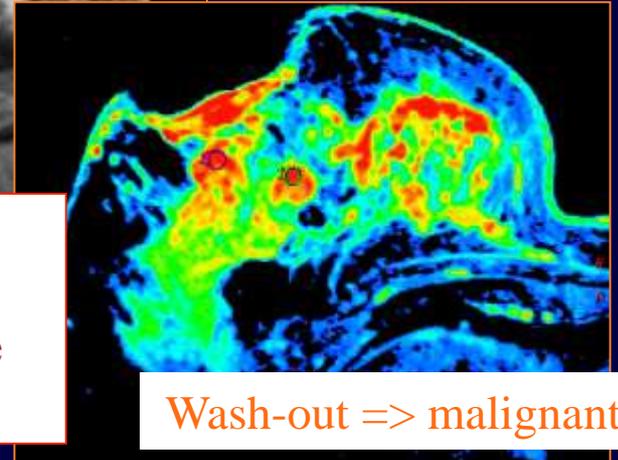
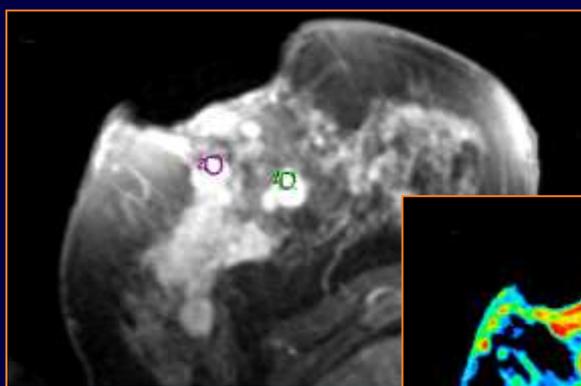
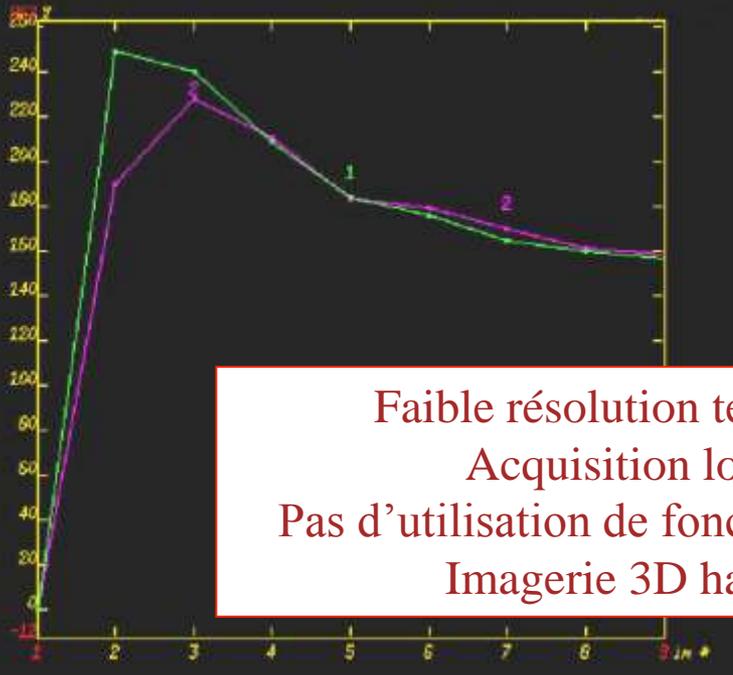
### DCE-MRI

- Hors Neurologie
- Tumeurs, inflammation, ischémie
- Perfusion et perméabilité
- Résolution temporelle variable

## Pondéré T2\*

### DSC

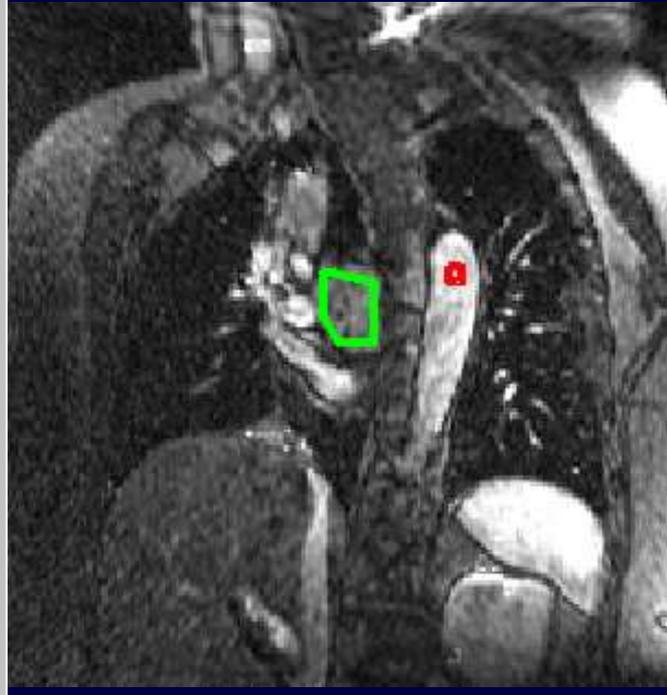
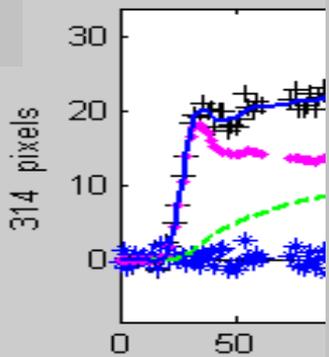
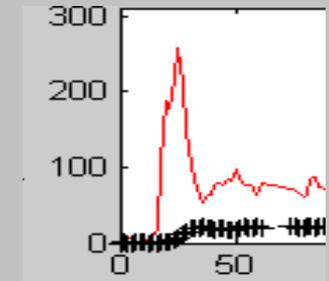
- Neurologie
- Ischémie
- Théoriquement pas tumeur
- Uniquement perfusion
- Haute résolution temporelle



Faible résolution temporelle (1i/60s)  
 Acquisition longue (8 min)  
 Pas d'utilisation de fonction d'entrée artérielle  
 Imagerie 3D haute résolution

Wash-out => malignant

Haute résolution temporelle (1i/2s)  
 Acquisition courte (90s)  
 Utilisation d'une fonction d'entrée  
 Acquisition 2D



F	53.5119	ml/min/100g	+/- 12.47 %
Vb	16.8457	%	+/- 20.57 %
PS	11.5485	ml/min/100g	+/- 46.46 %
Ve	9.2404	%	+/- 25.98 %
Dt	4.303	s	+/- 15.39 %
Aire relative	0.313891		

Echelle

# Paramètres principaux de microcirculation

Débit de  
Perfusion  
tissulaire  
(ml/min/100ml)

Volume interstitiel (%)

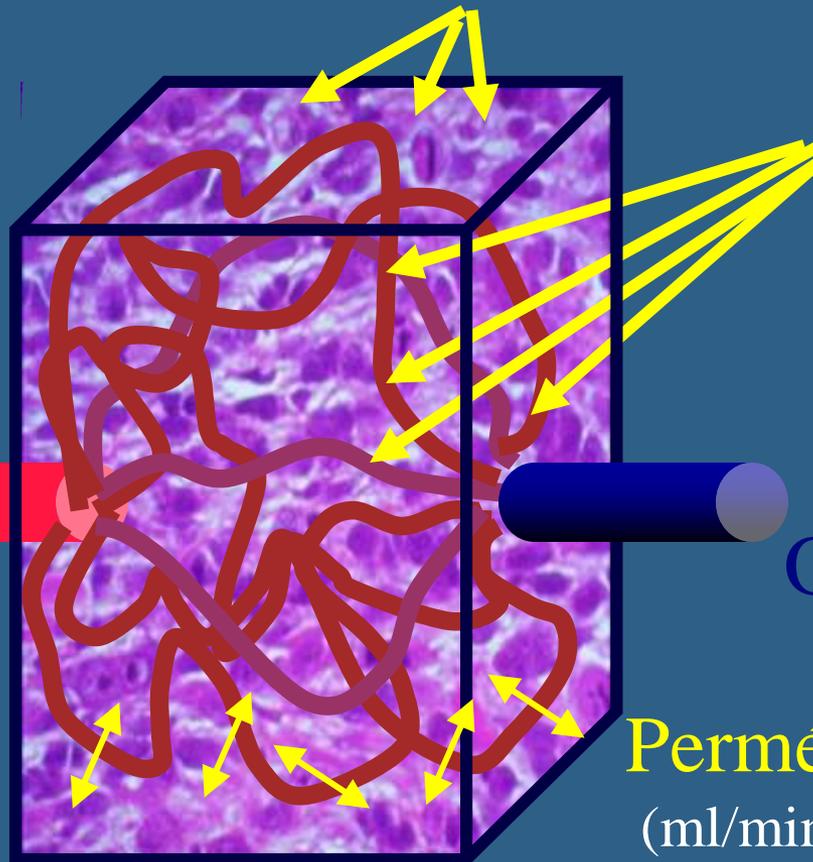
Volume  
sanguin  
tissulaire  
(%)

IN

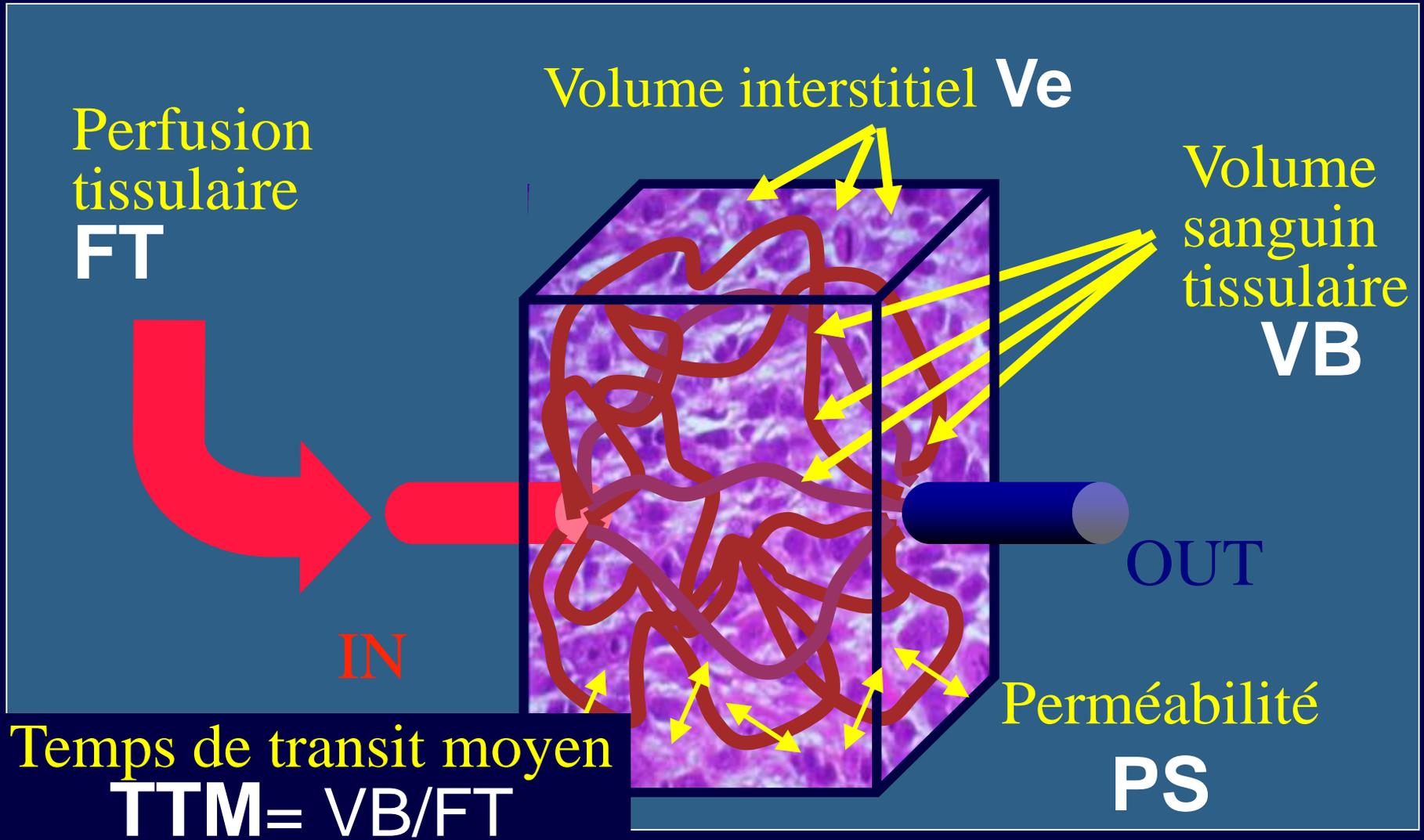
OUT

Perméabilité  
(ml/min/100ml)

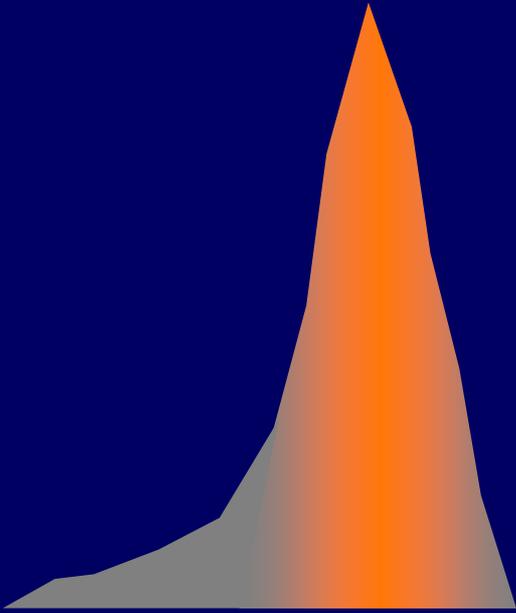
Dépend du traceur



# Paramètres principaux de microcirculation

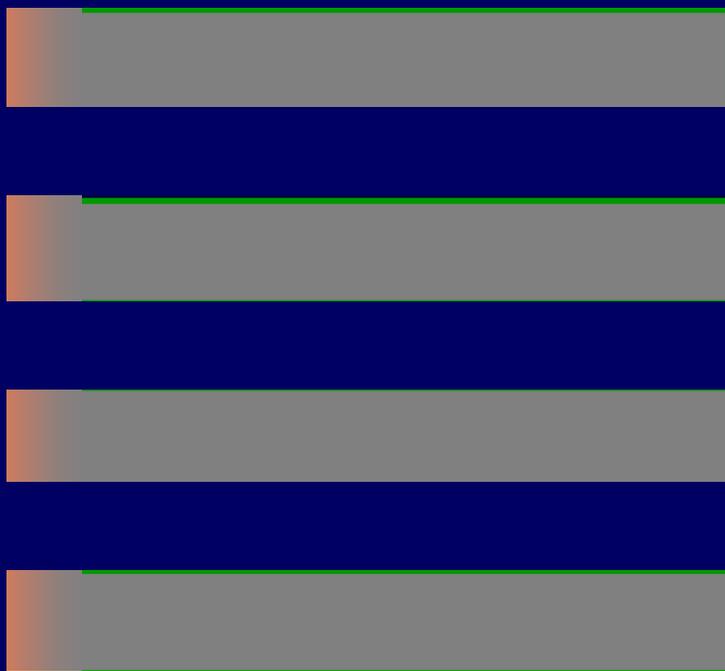
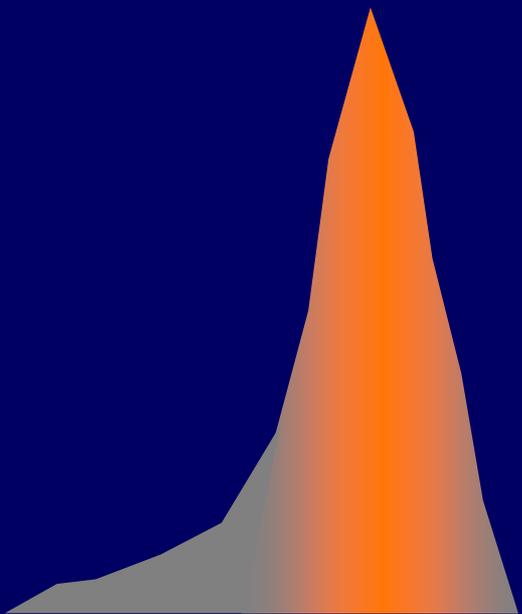


# Fonction d'entrée artérielle



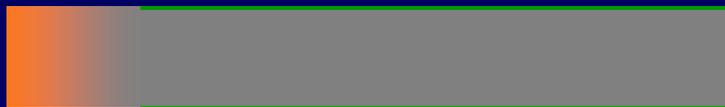
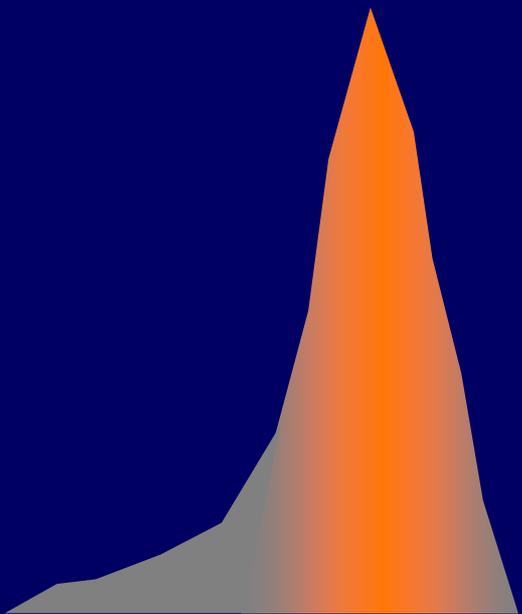
Réponse tissulaire

---



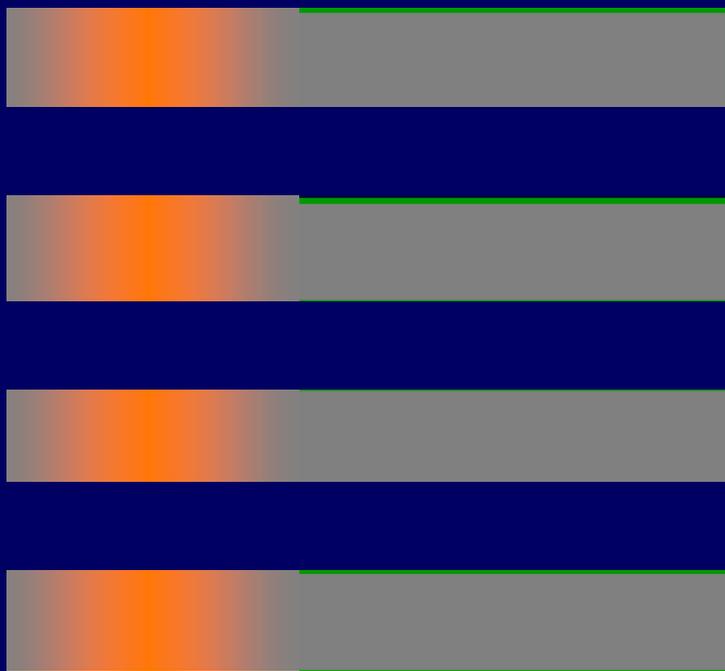
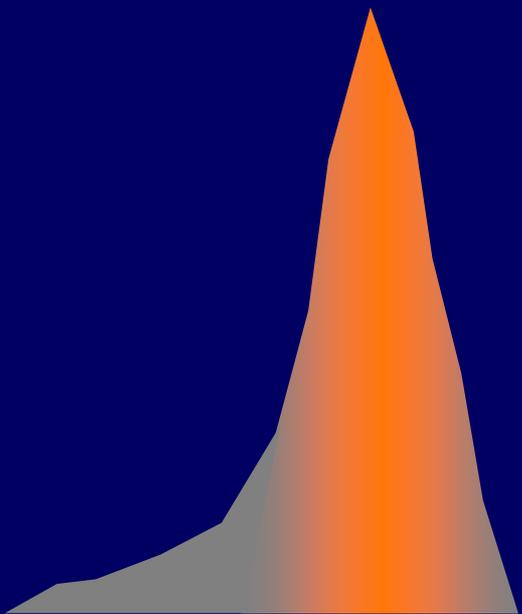
Tissue response





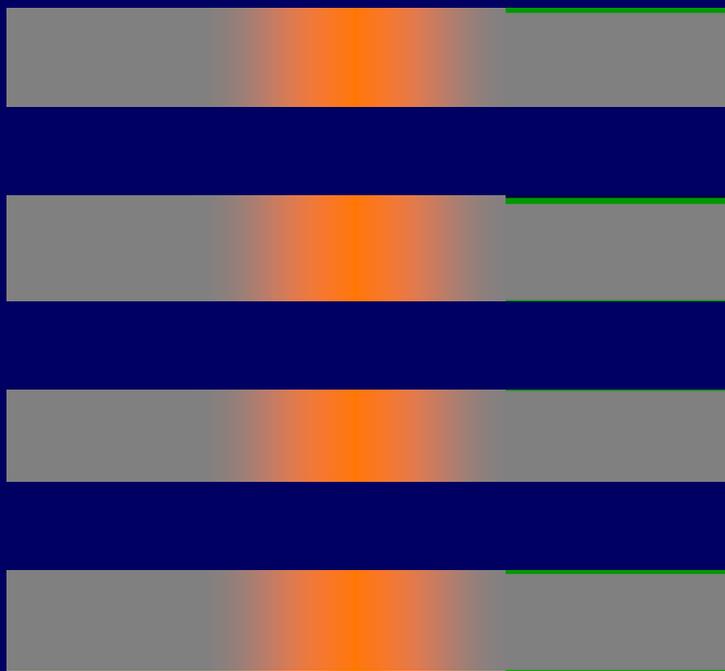
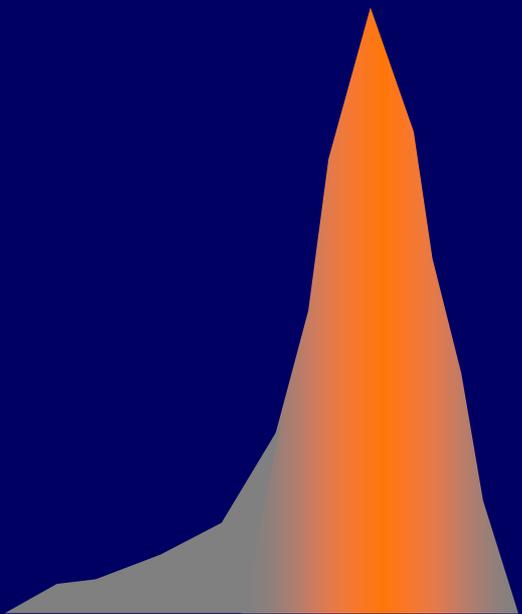
Tissue response





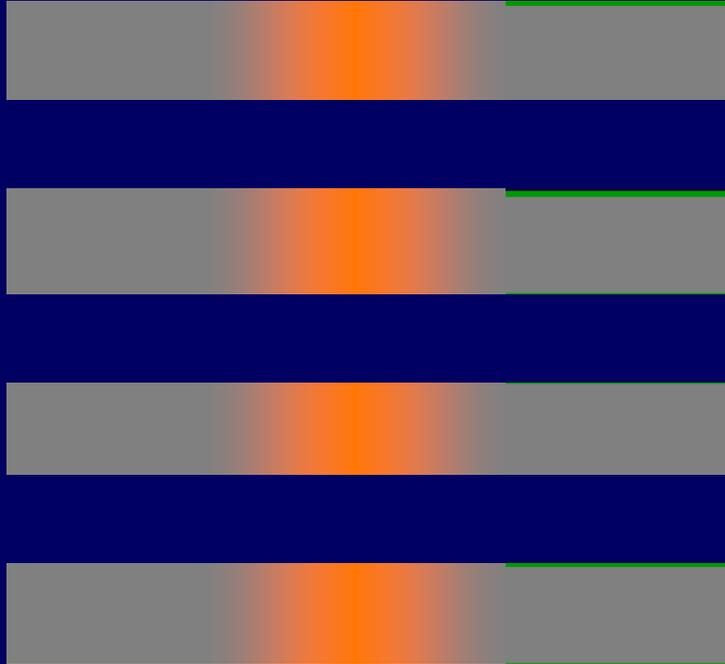
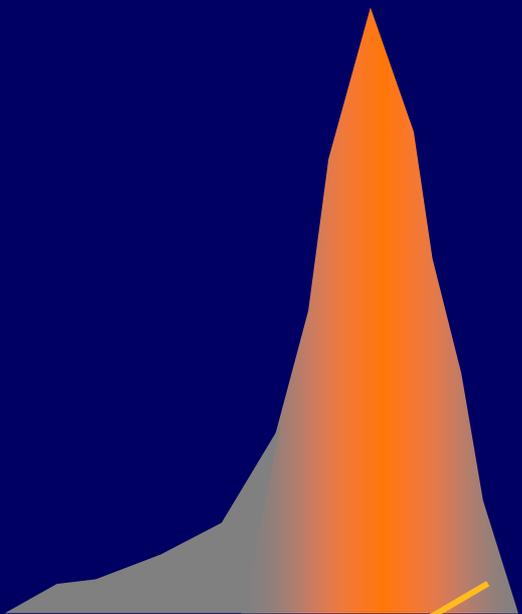
Tissue response





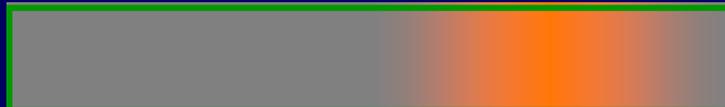
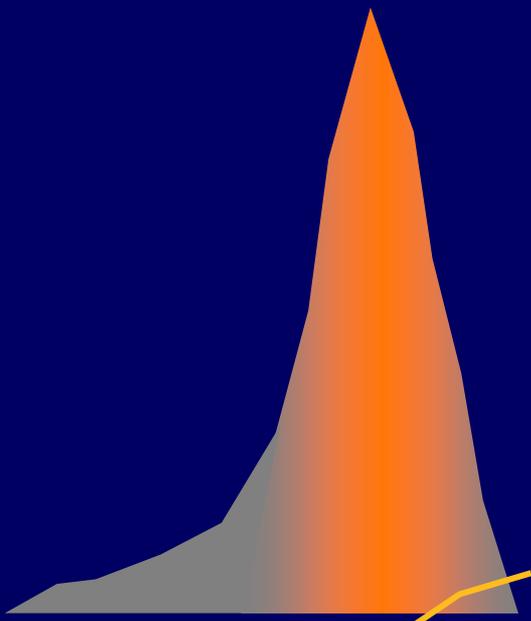
Tissue response





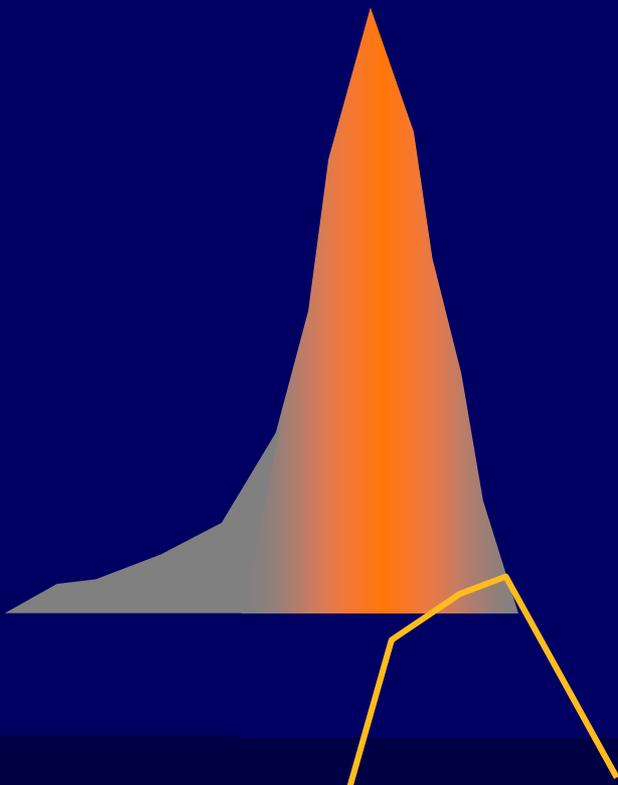
Tissue response



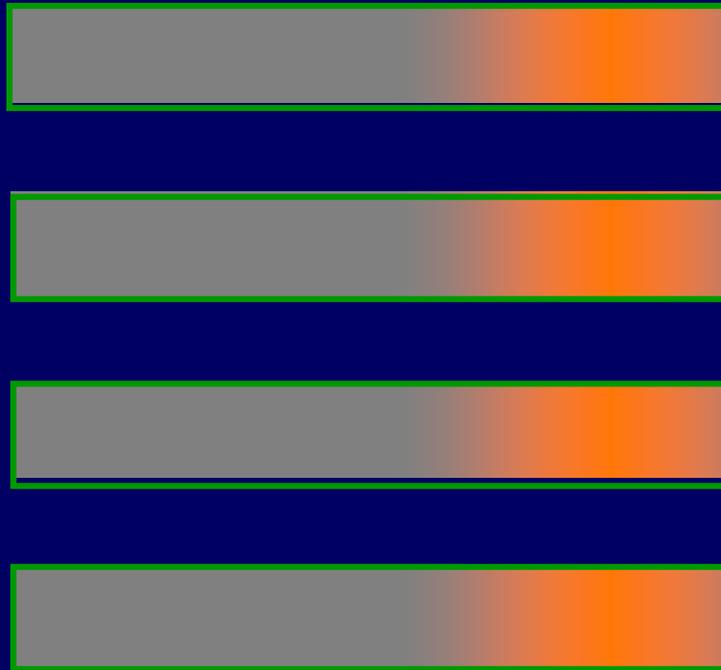


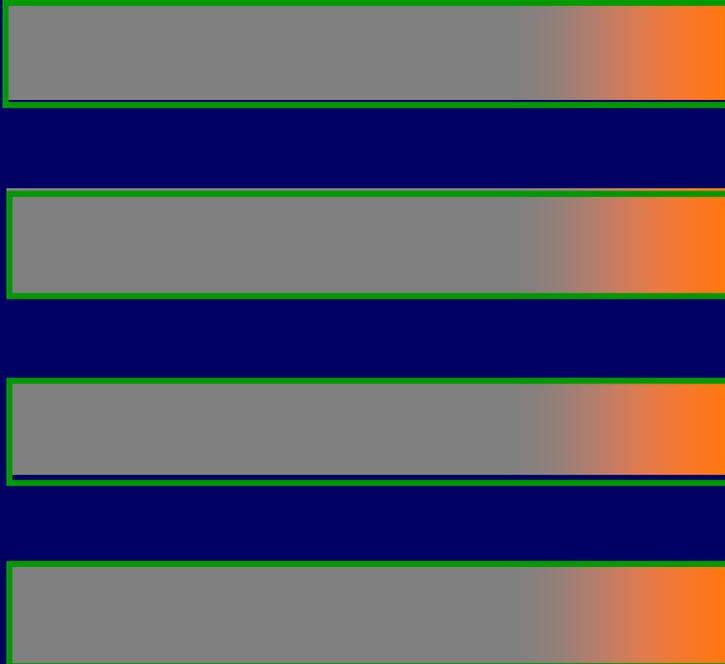
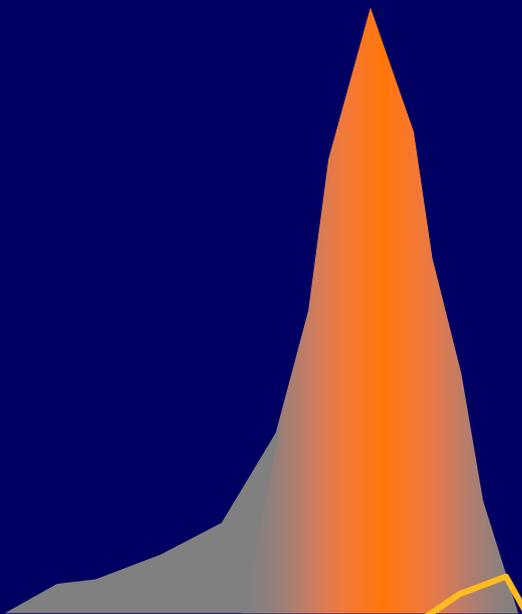
Tissue response





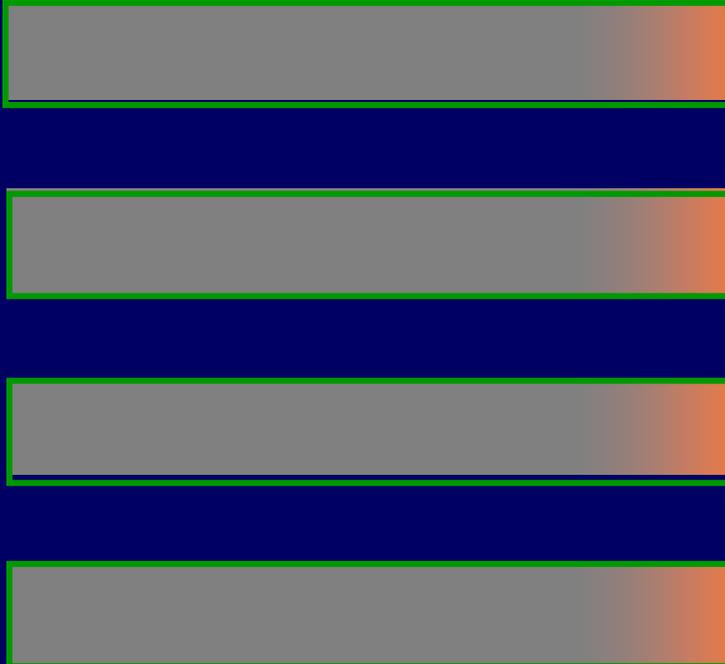
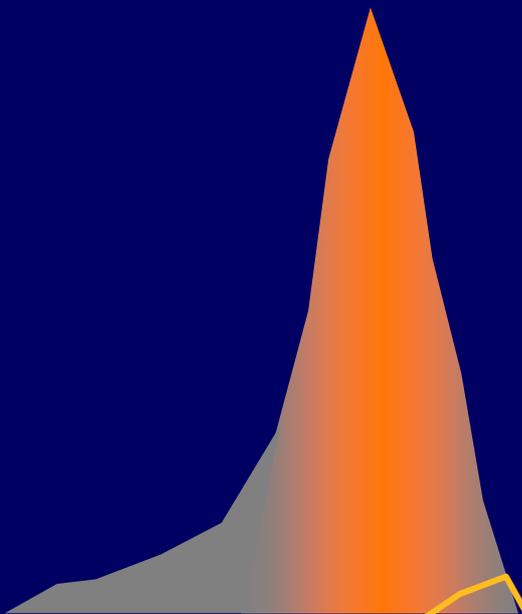
Tissue response



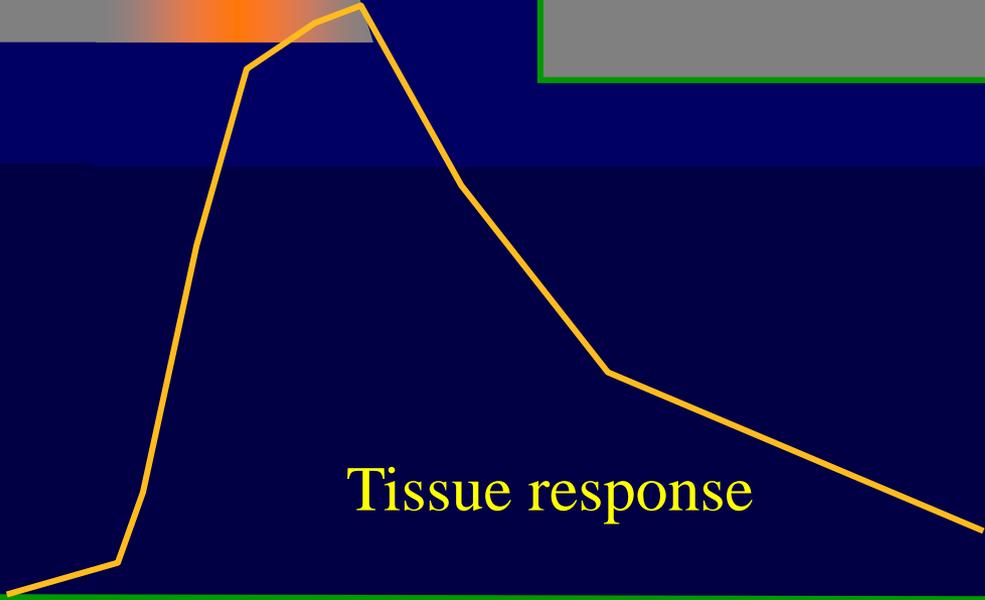


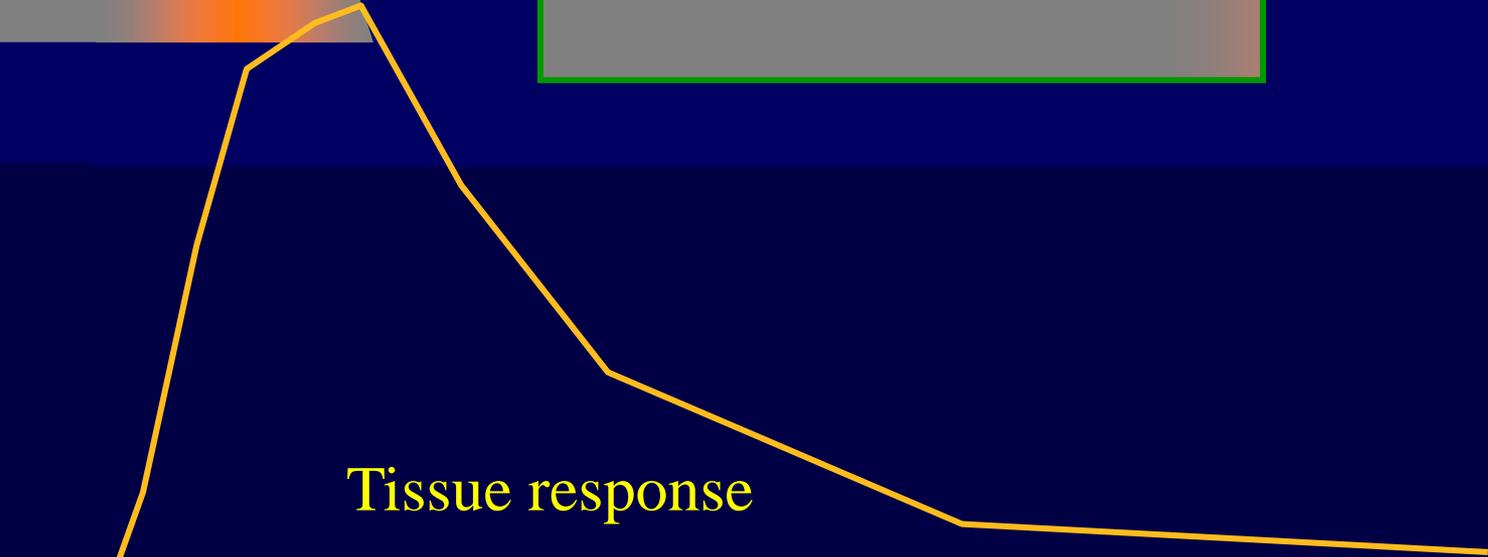
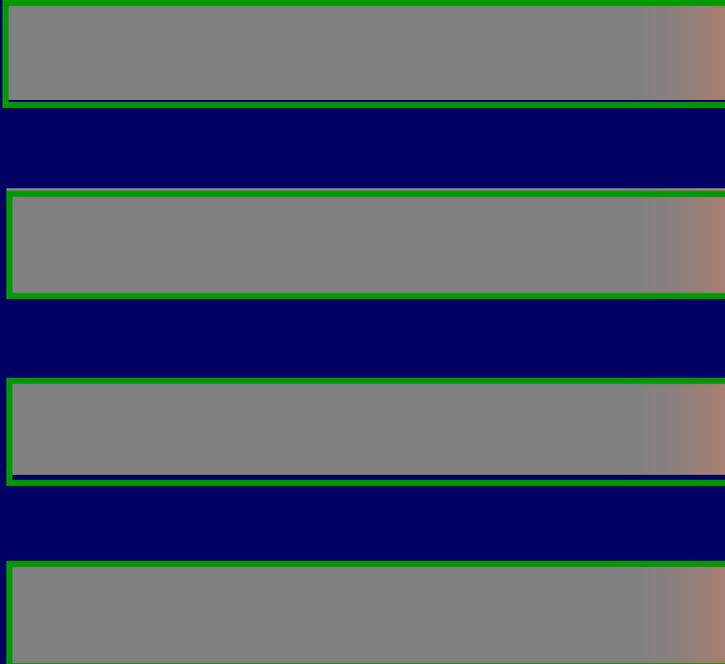
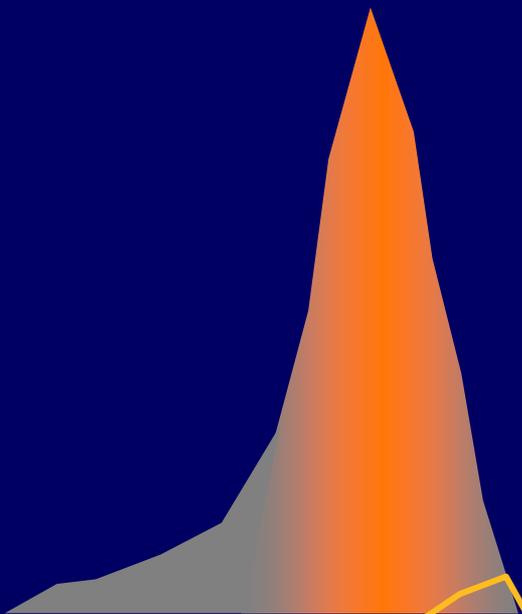
Tissue response



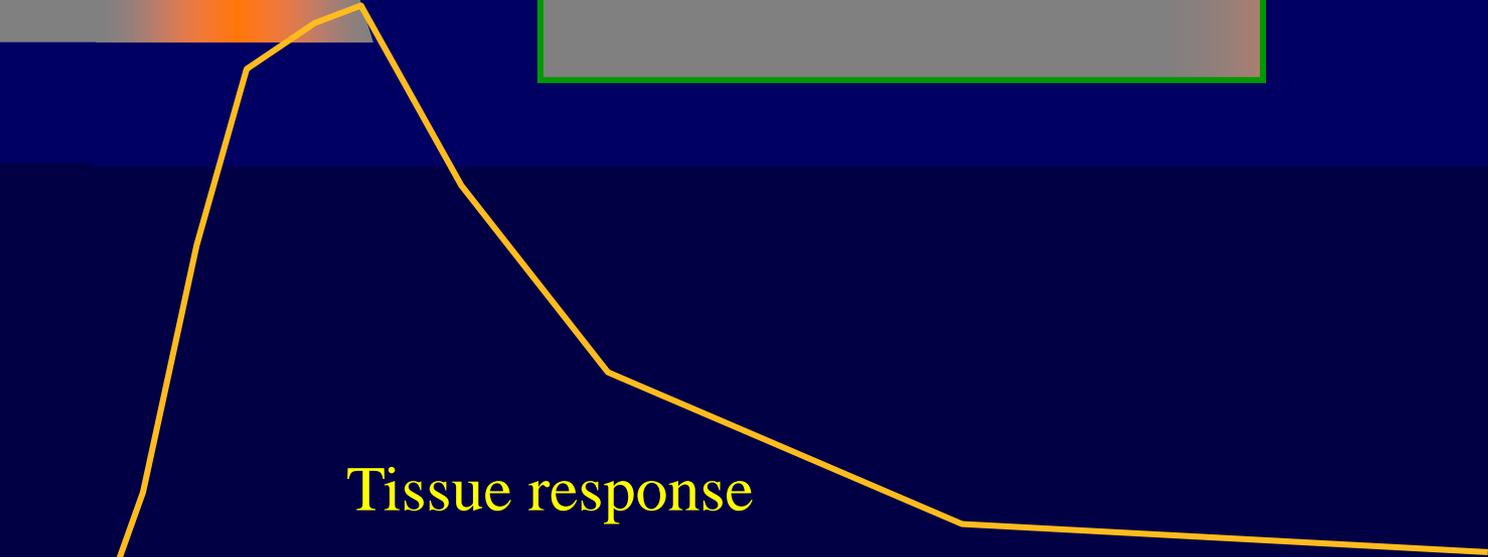
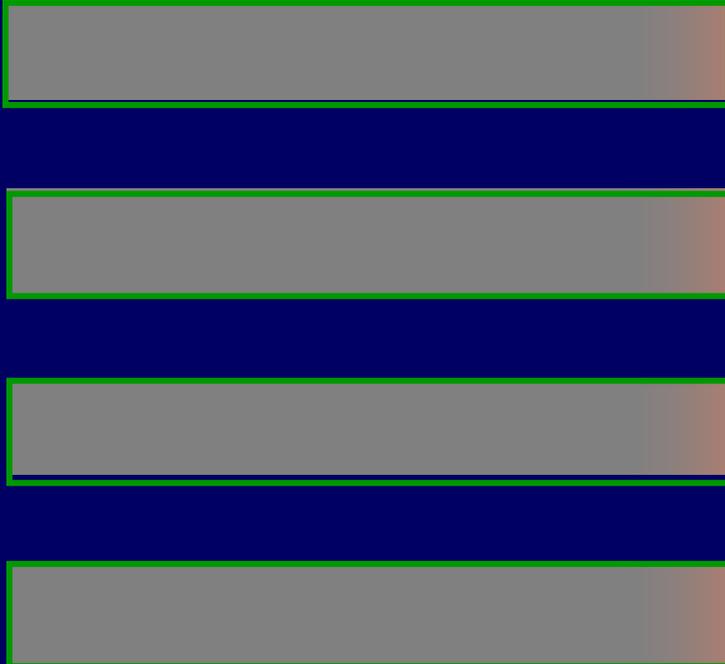
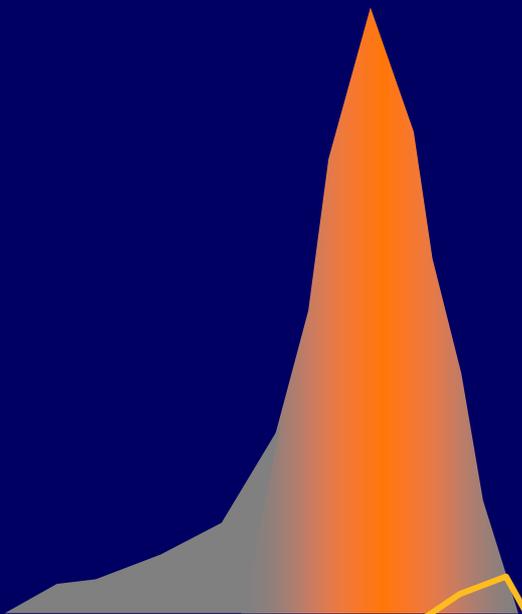


Tissue response

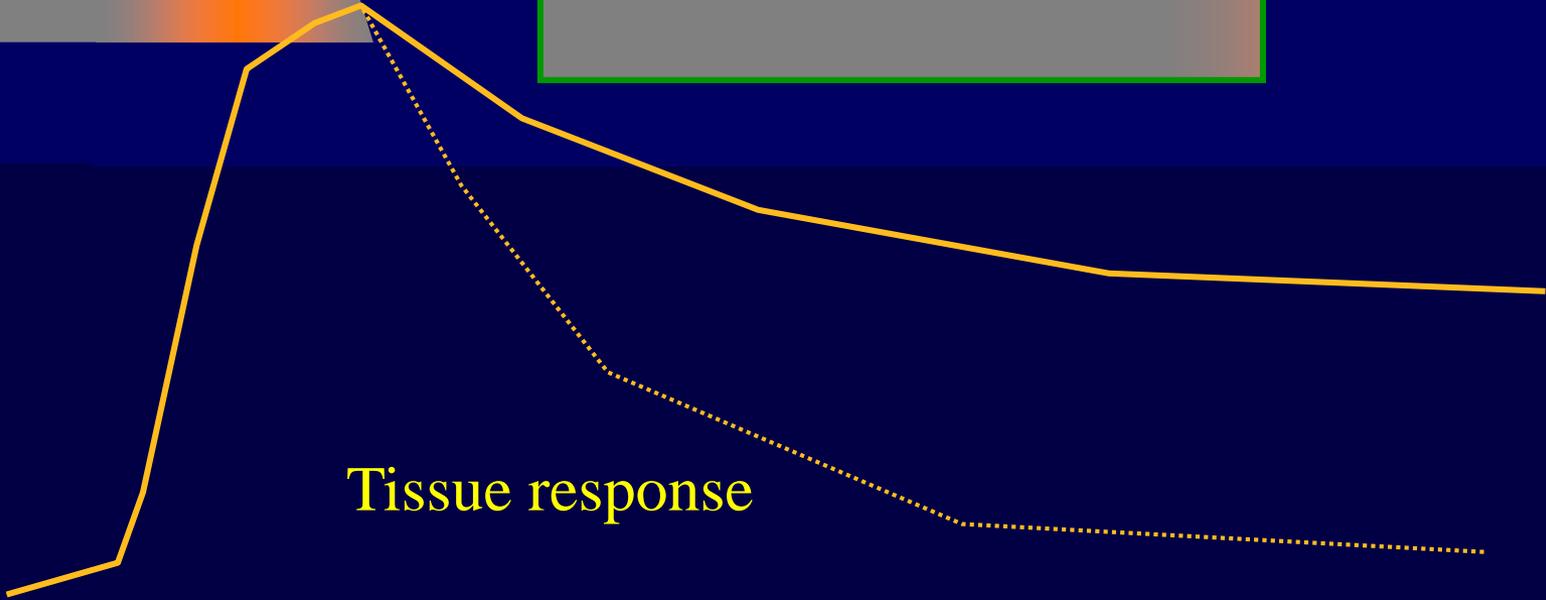
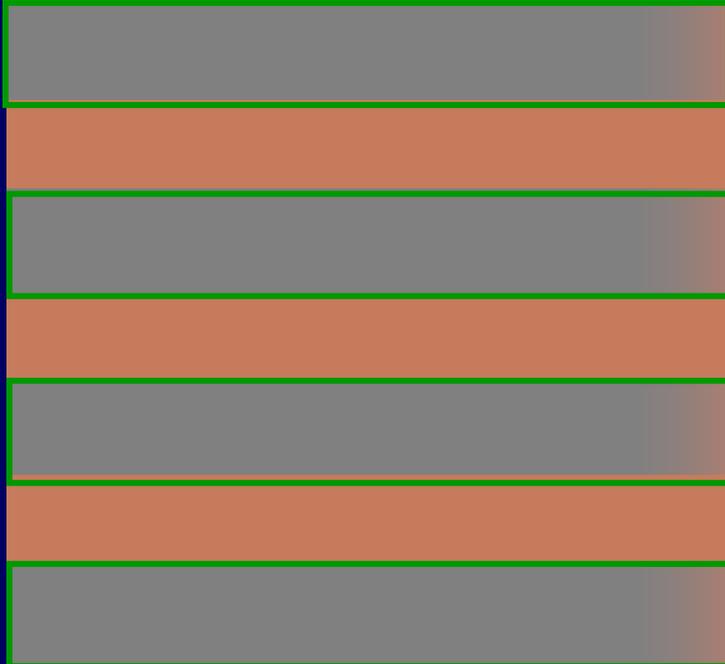
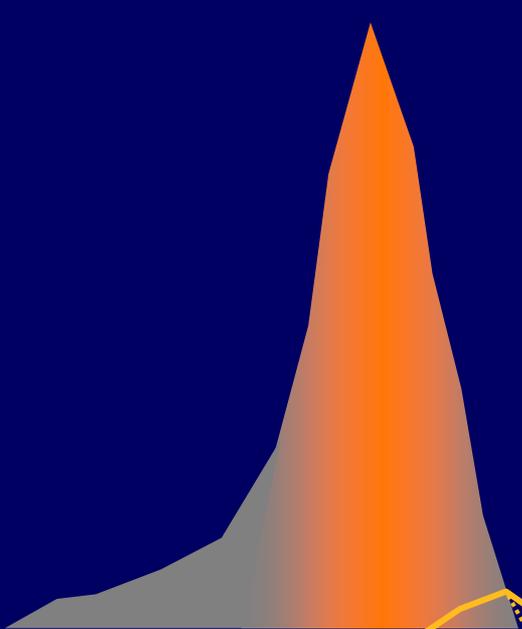




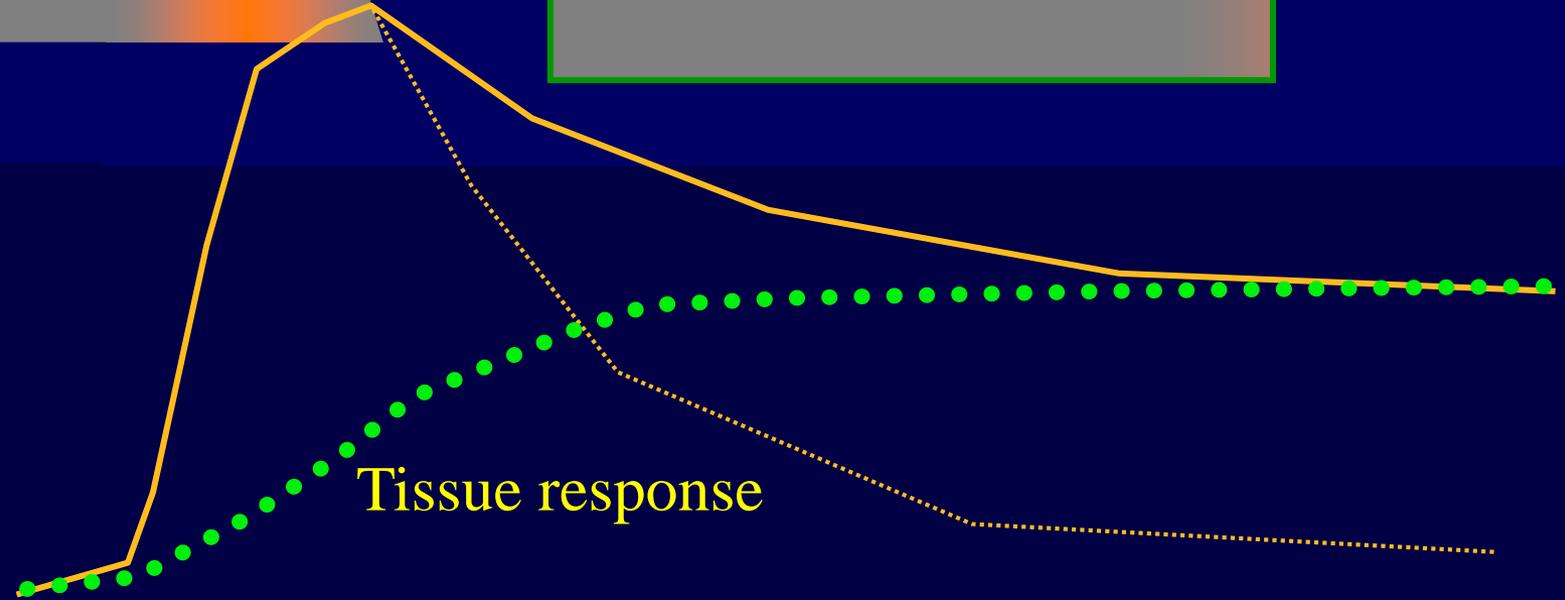
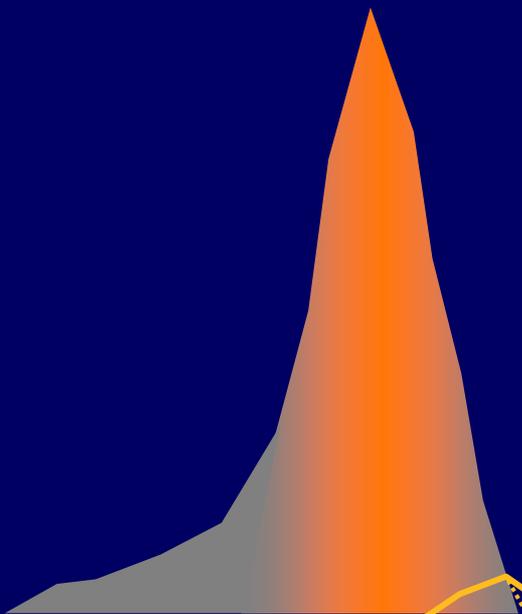
Tissue response



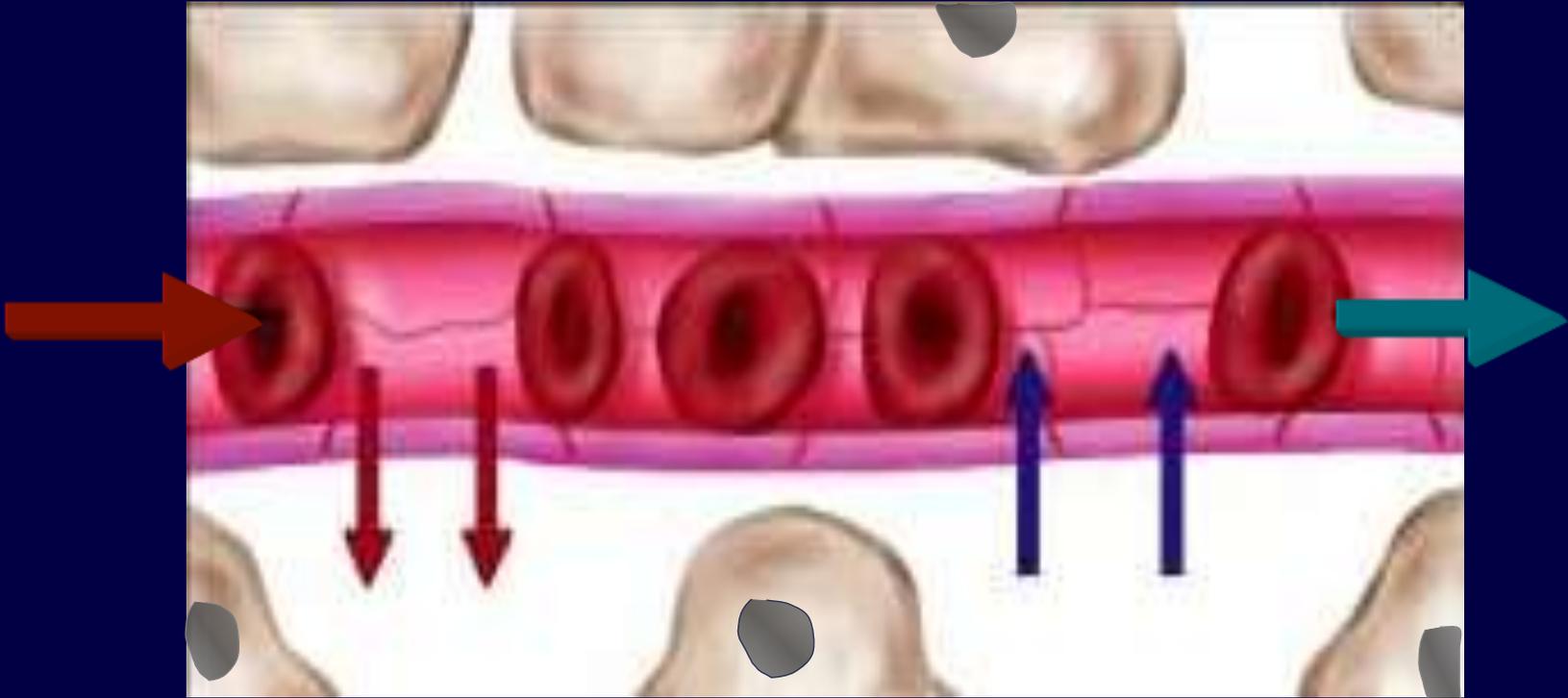
Tissue response



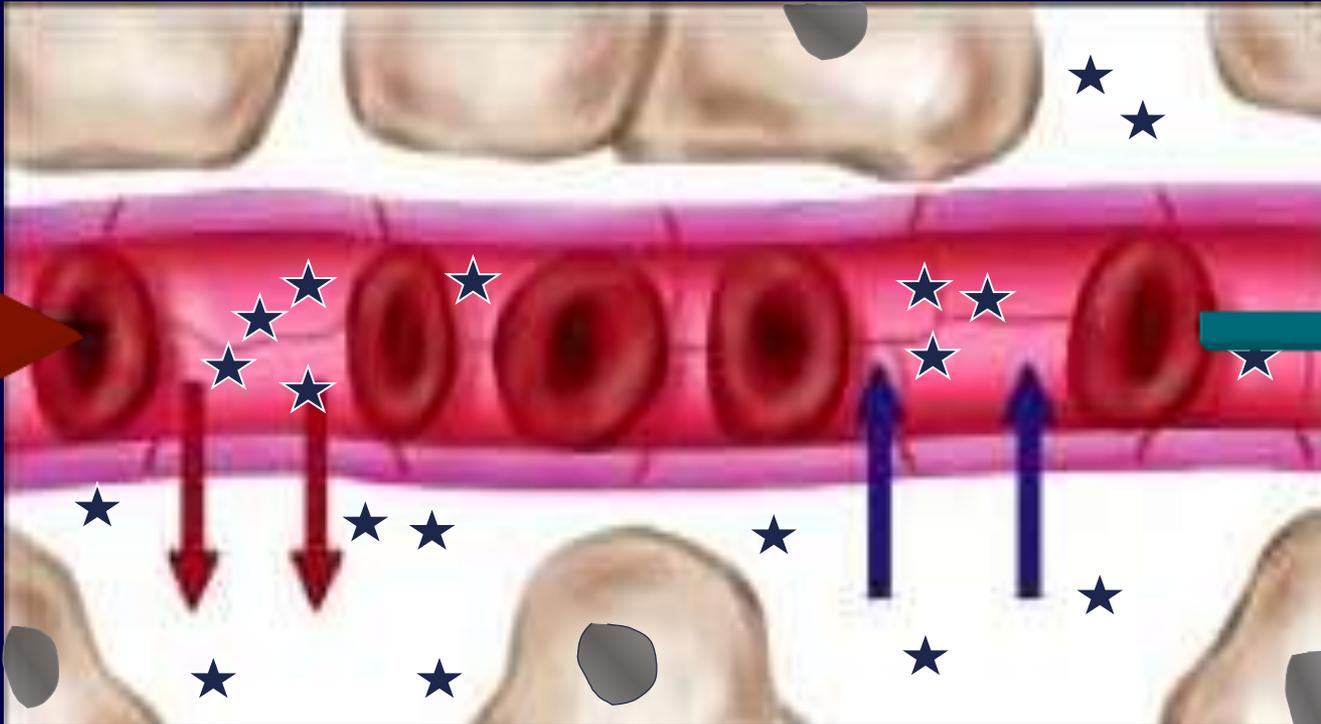
Tissue response



Tissue response

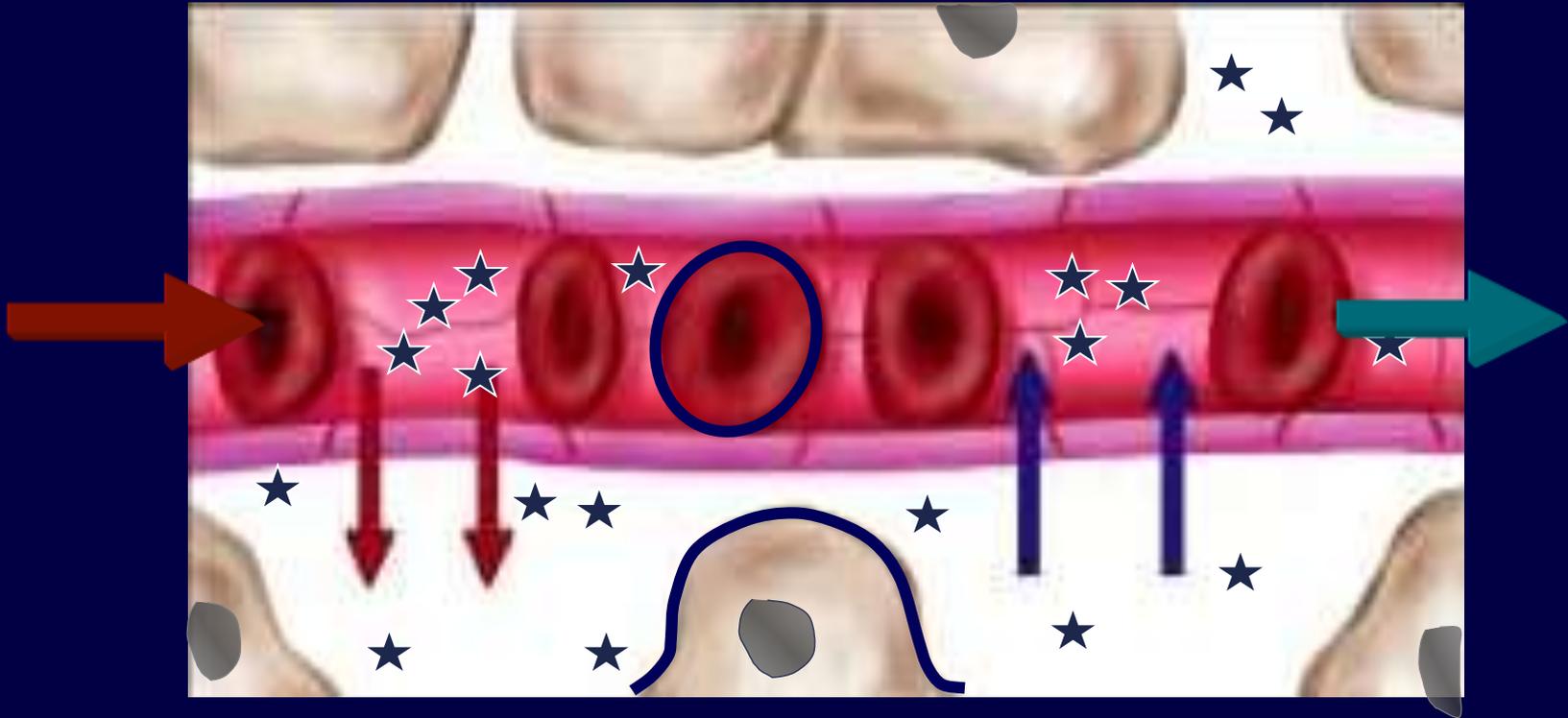


# Agent de contraste à diffusion extra-vasculaire extra-cellulaire



CT et IRM

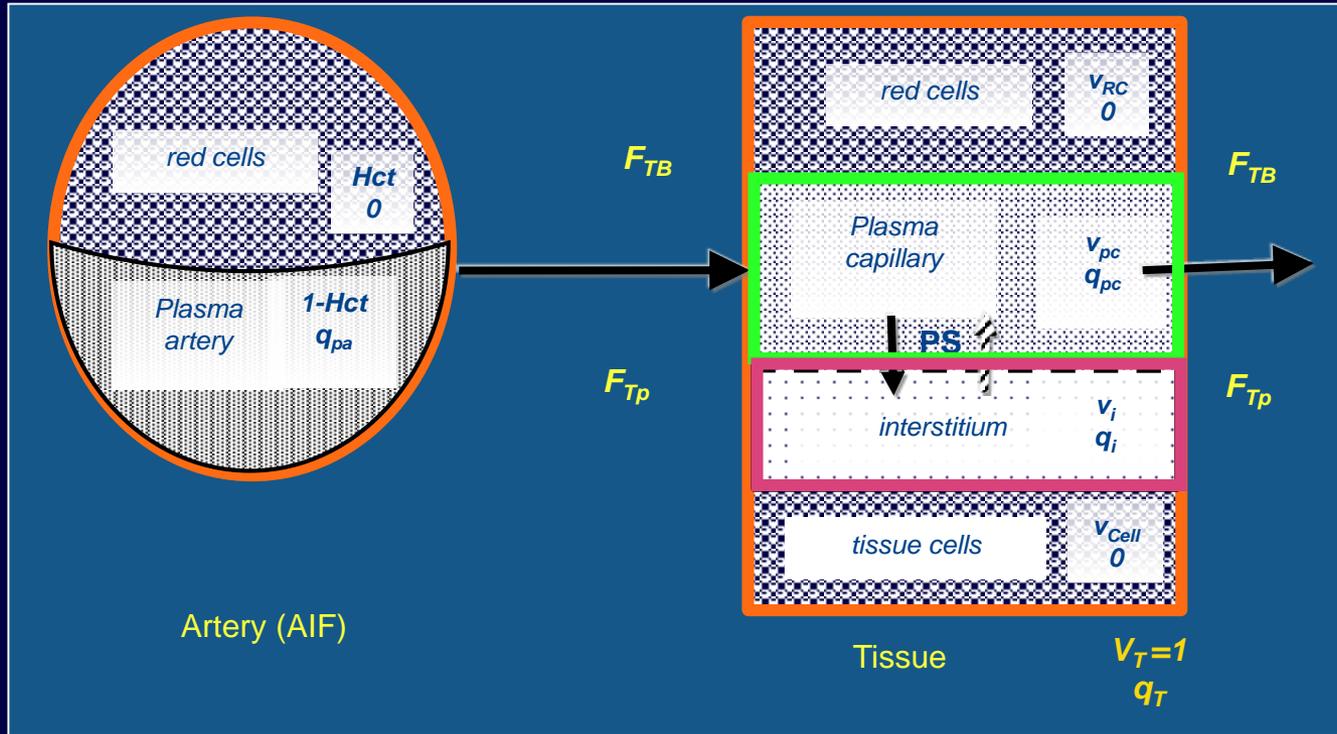
# Agents de contraste diffusants dans l'interstitium



*Ne diffusent pas dans les cellules +++*

# Modèle unifié complet

*acquisition rapide / longue durée d'acquisition*



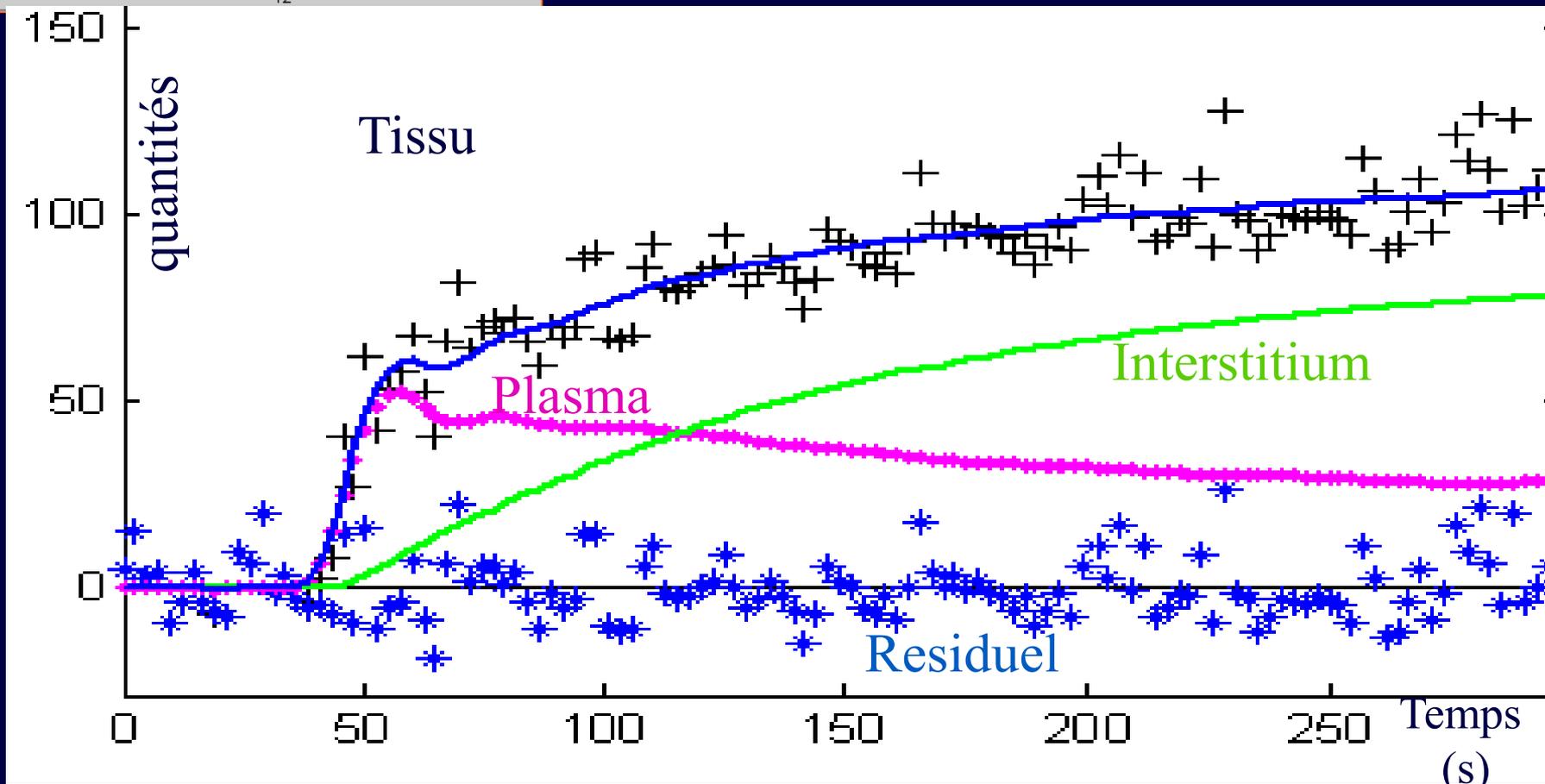
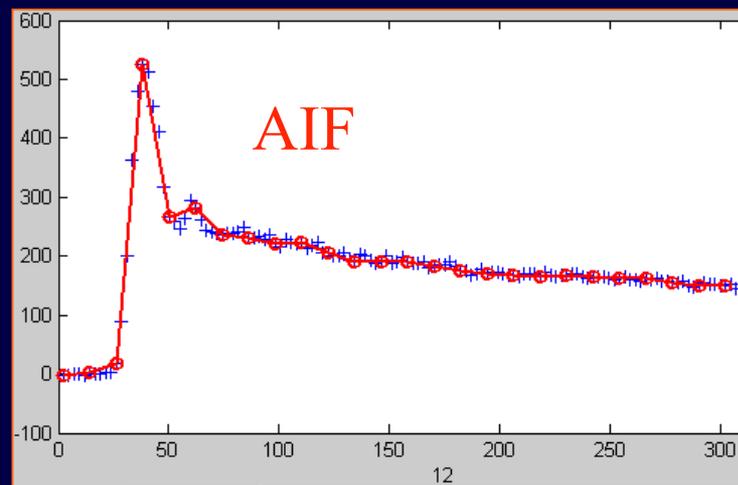
$$q_T = q_{pc} + q_i$$

$$q_{pc}(i+1) = q_{pc}(i) + dt[F_{Tp} * q_{pa}(i+1) - F_{Tp} * q_{pc}(i) / v_{pc} - PS * q_{pc}(i) / v_{pc} + PS * q_i(i) / v_i]$$

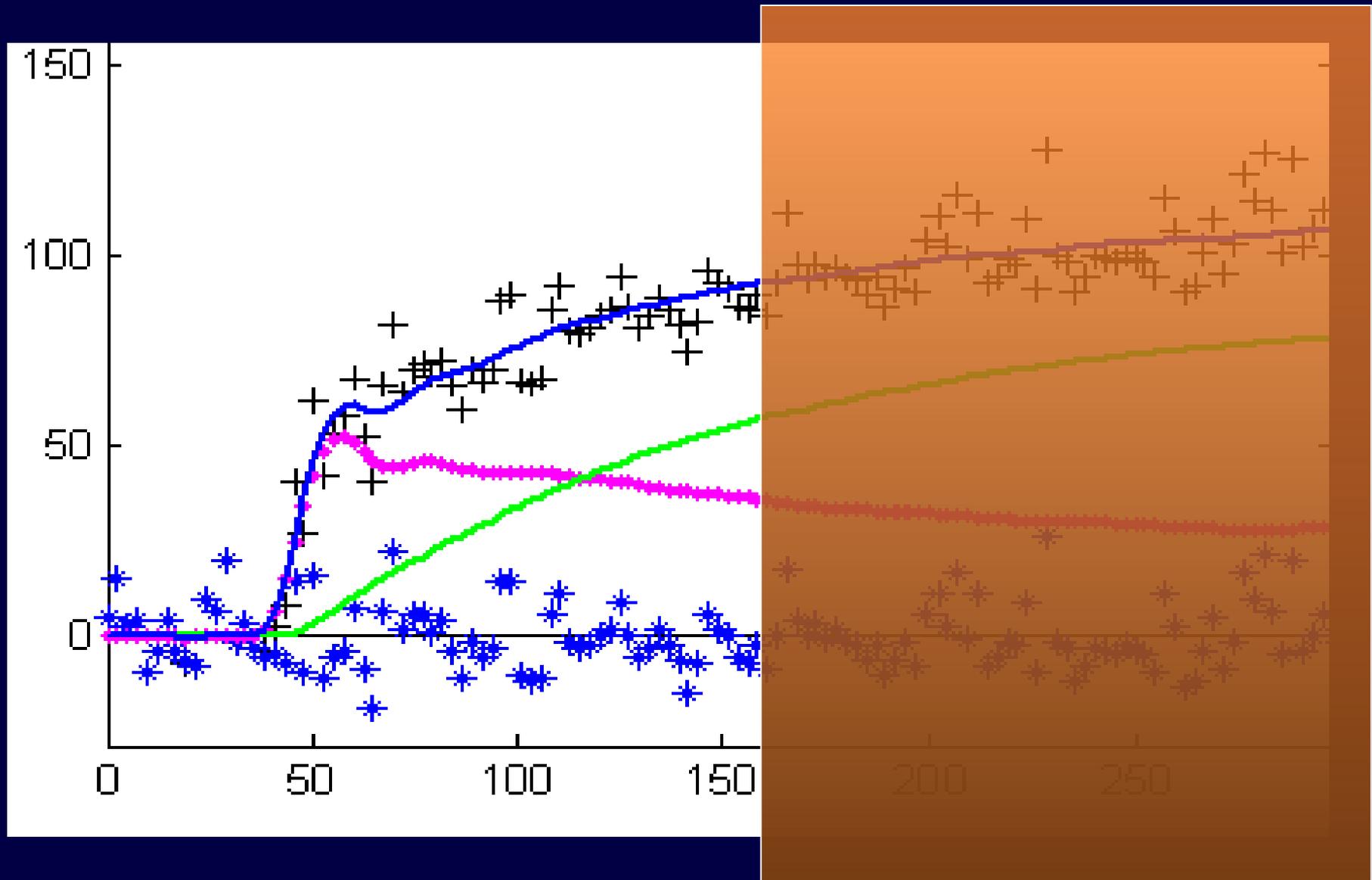
$$q_i(i+1) = q_i(i) + dt[PS * q_{pc}(i) / v_p - PS * q_i(i) / v_i]$$

# Modèle complet

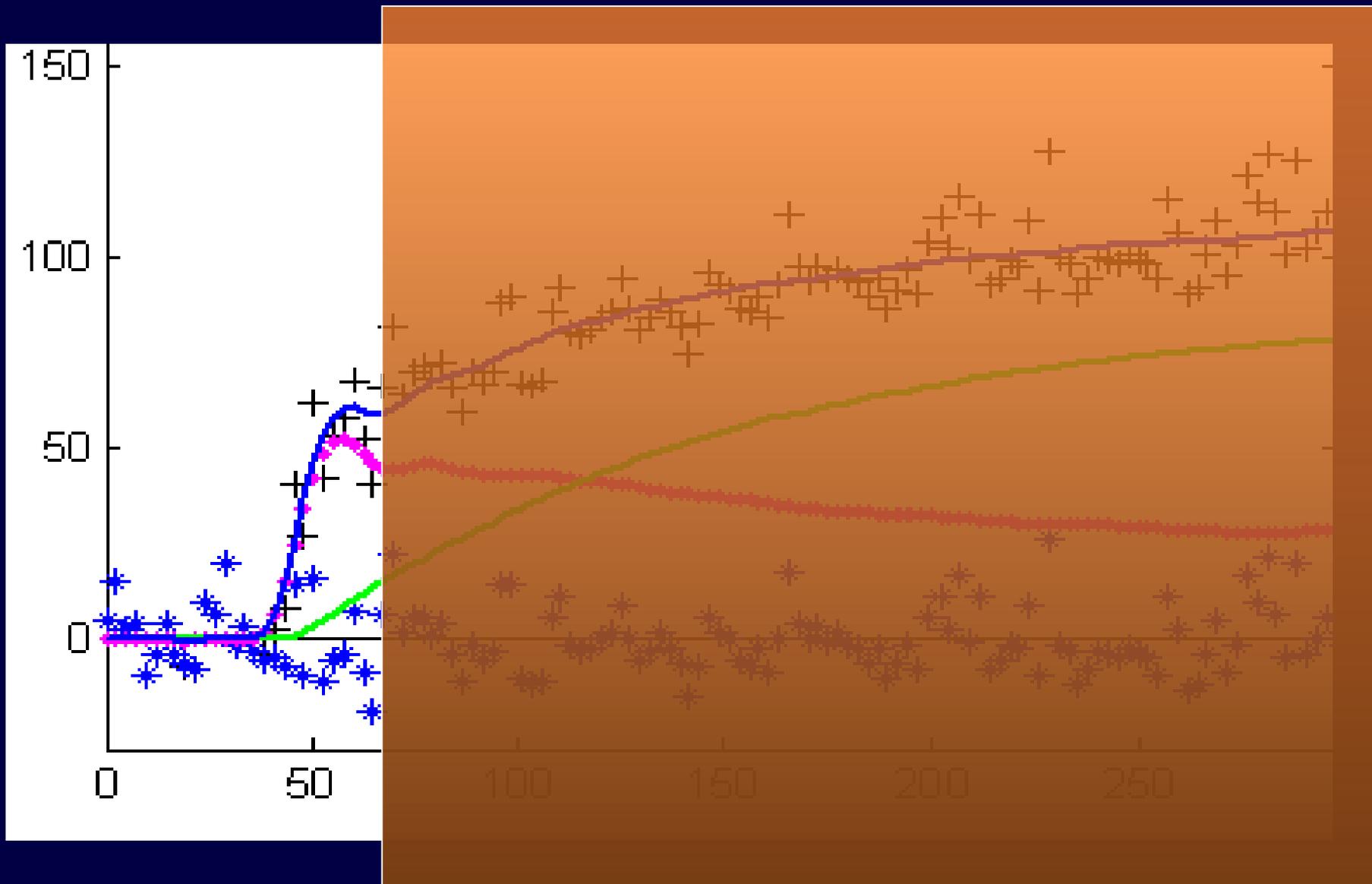
*Haute résolution temporelle  
acquisition longue*



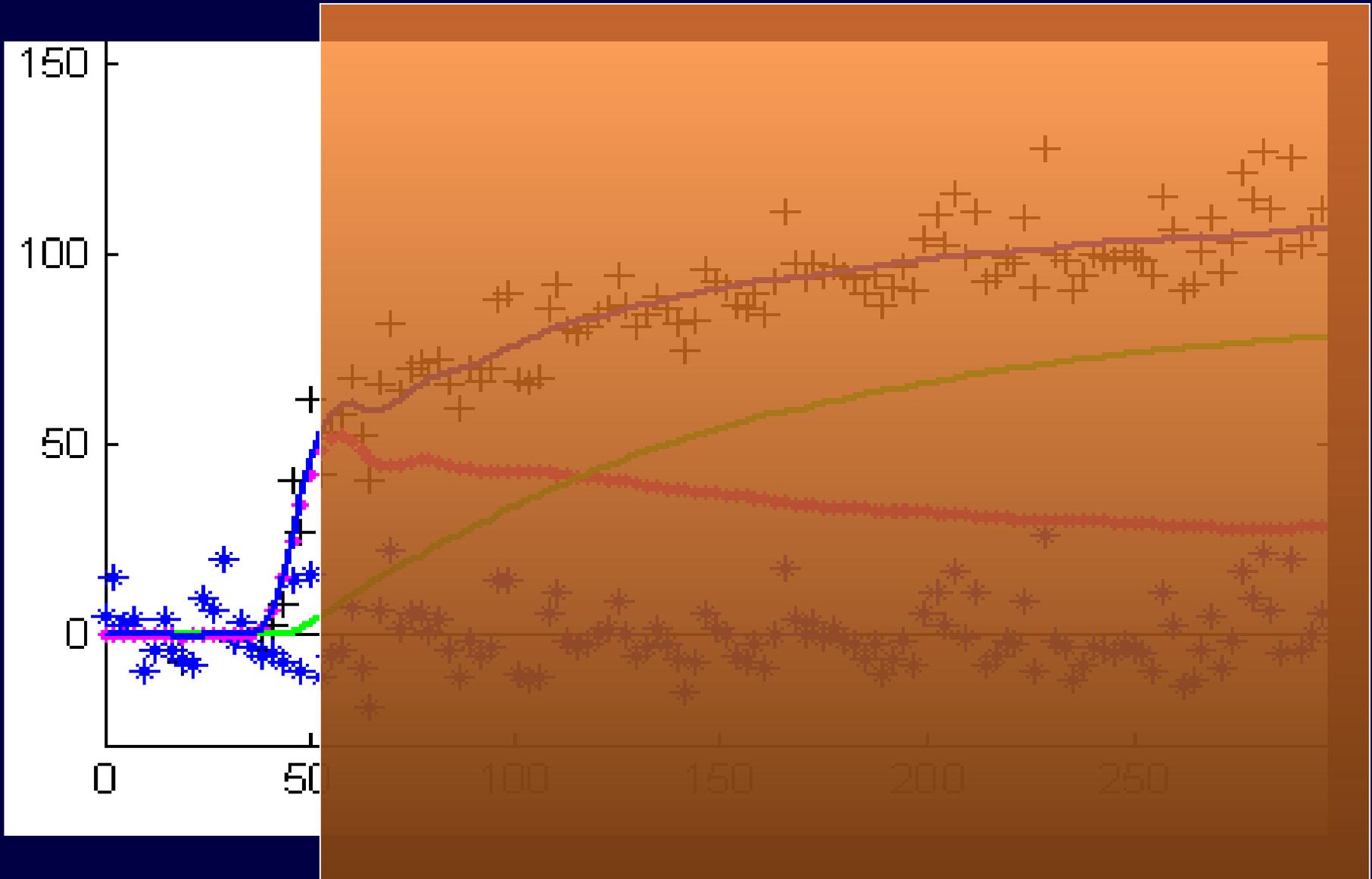
# Durée d'acquisition moyenne



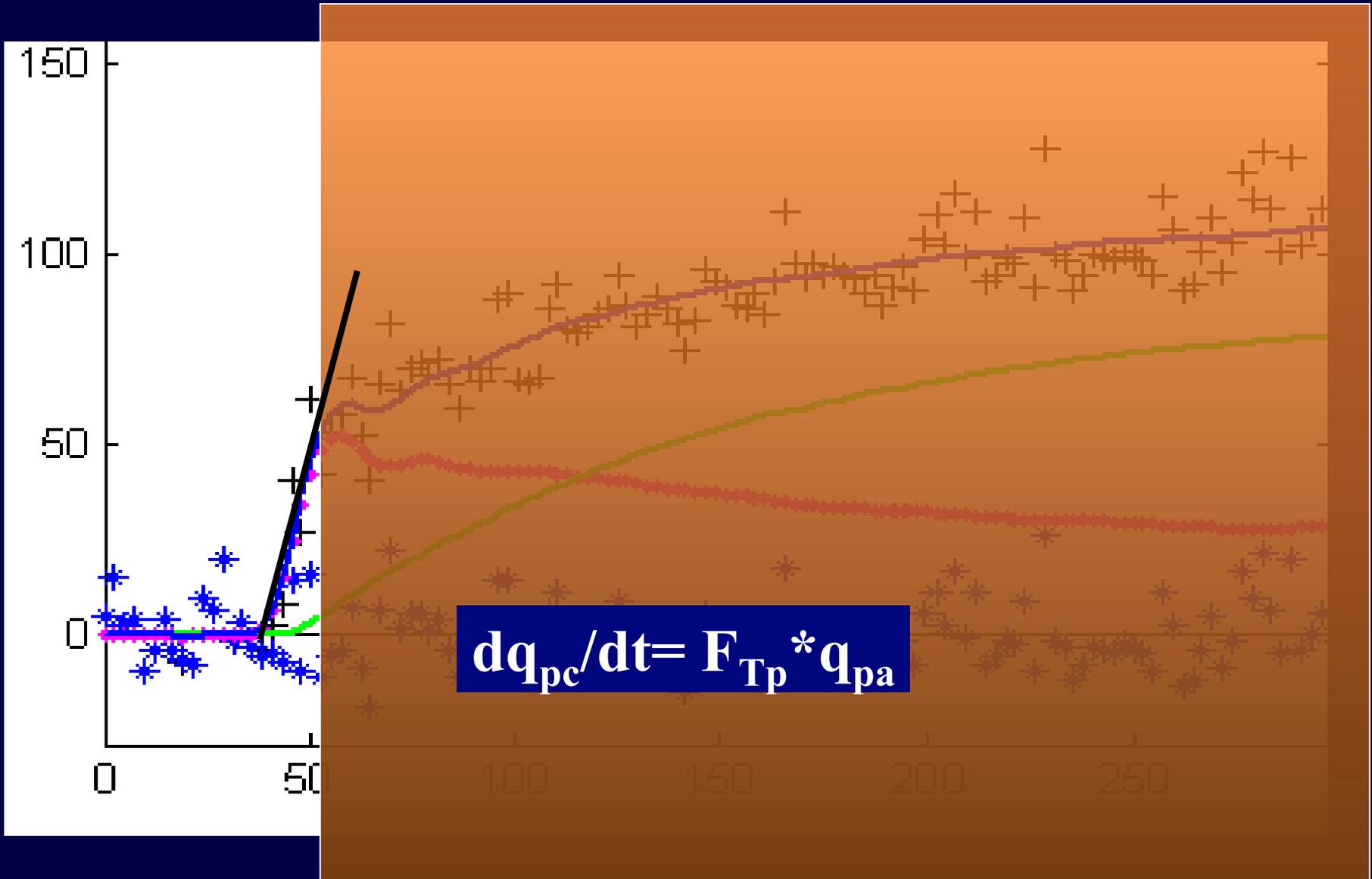
# Acquisition très courte (1er passage)



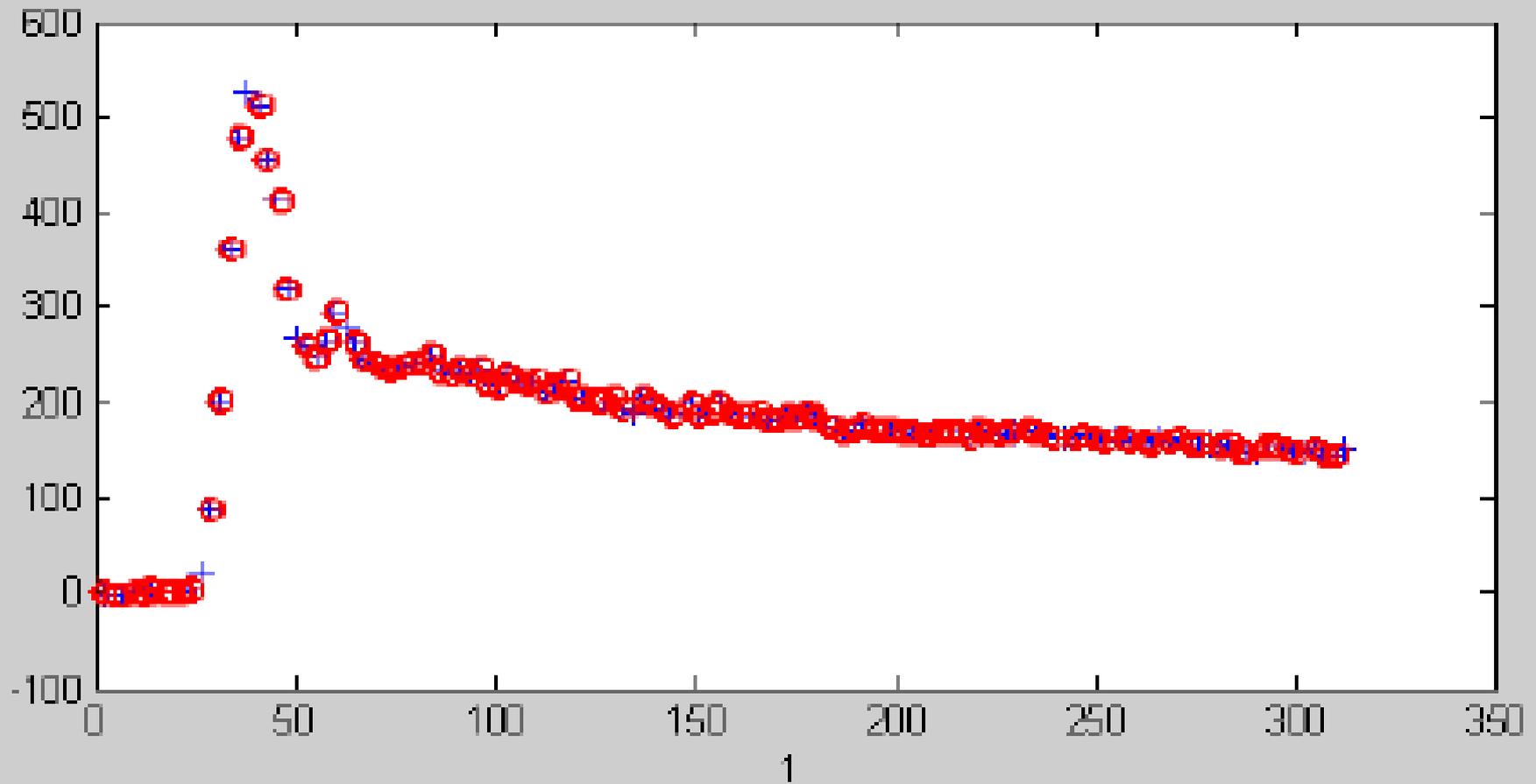
# Acquisition ultra-courte (méthode des pentes)

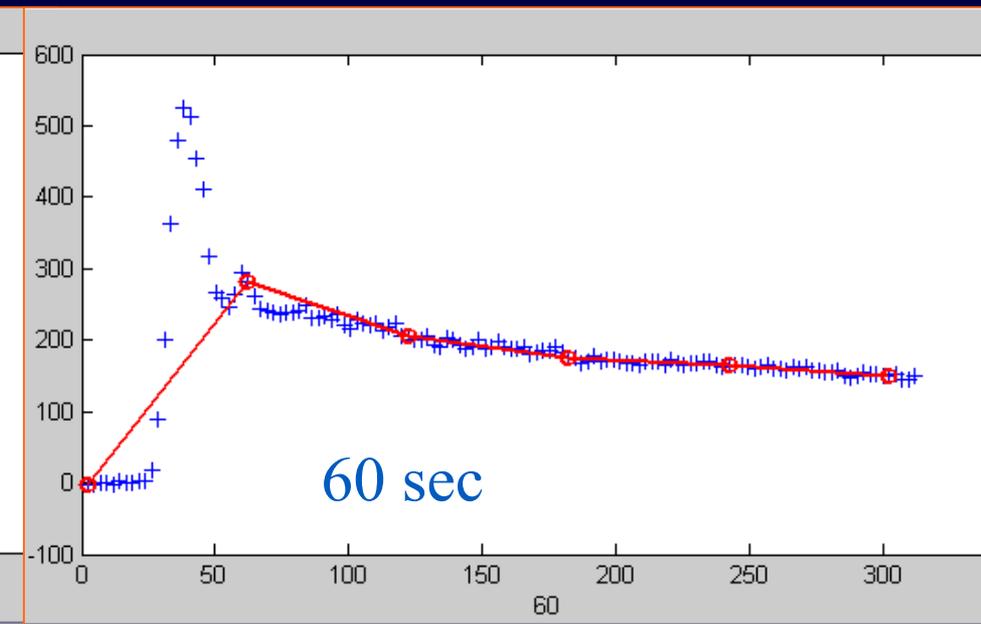
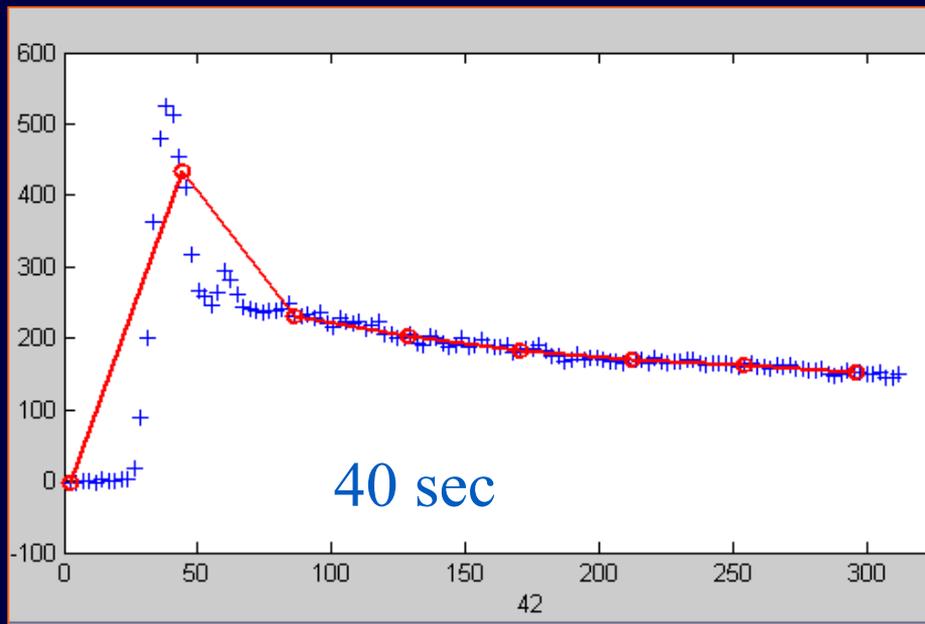
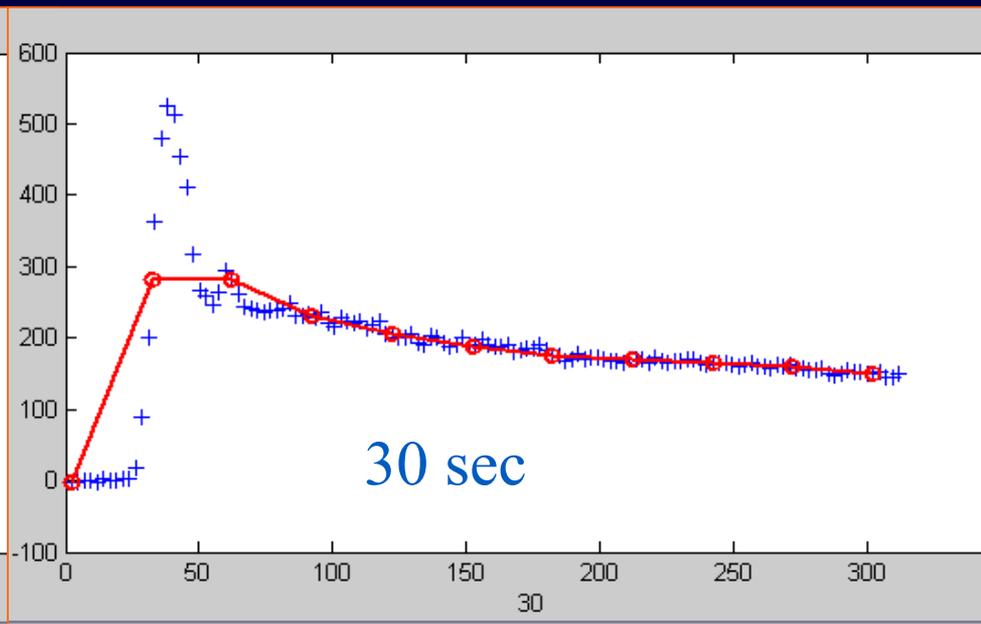
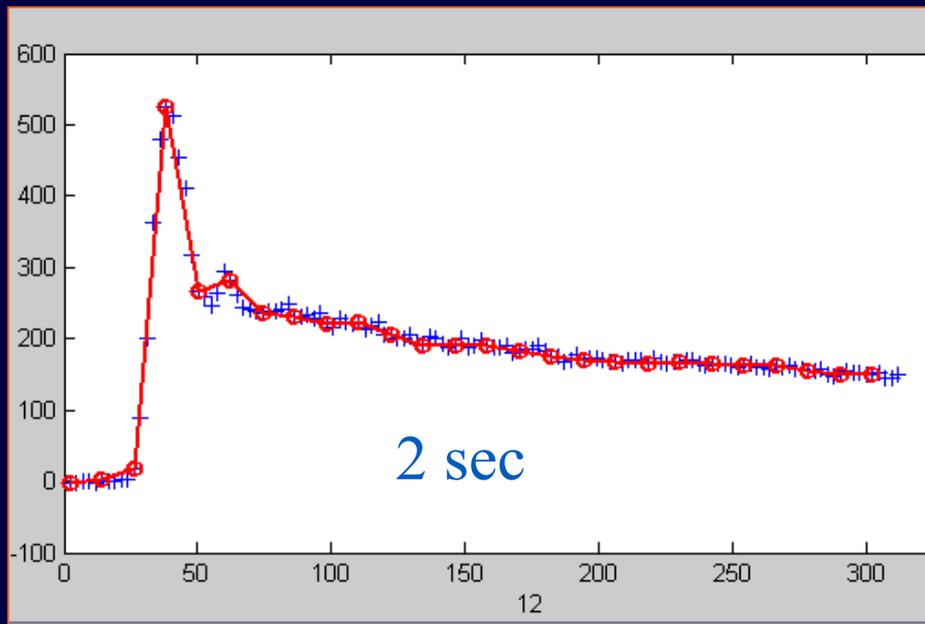


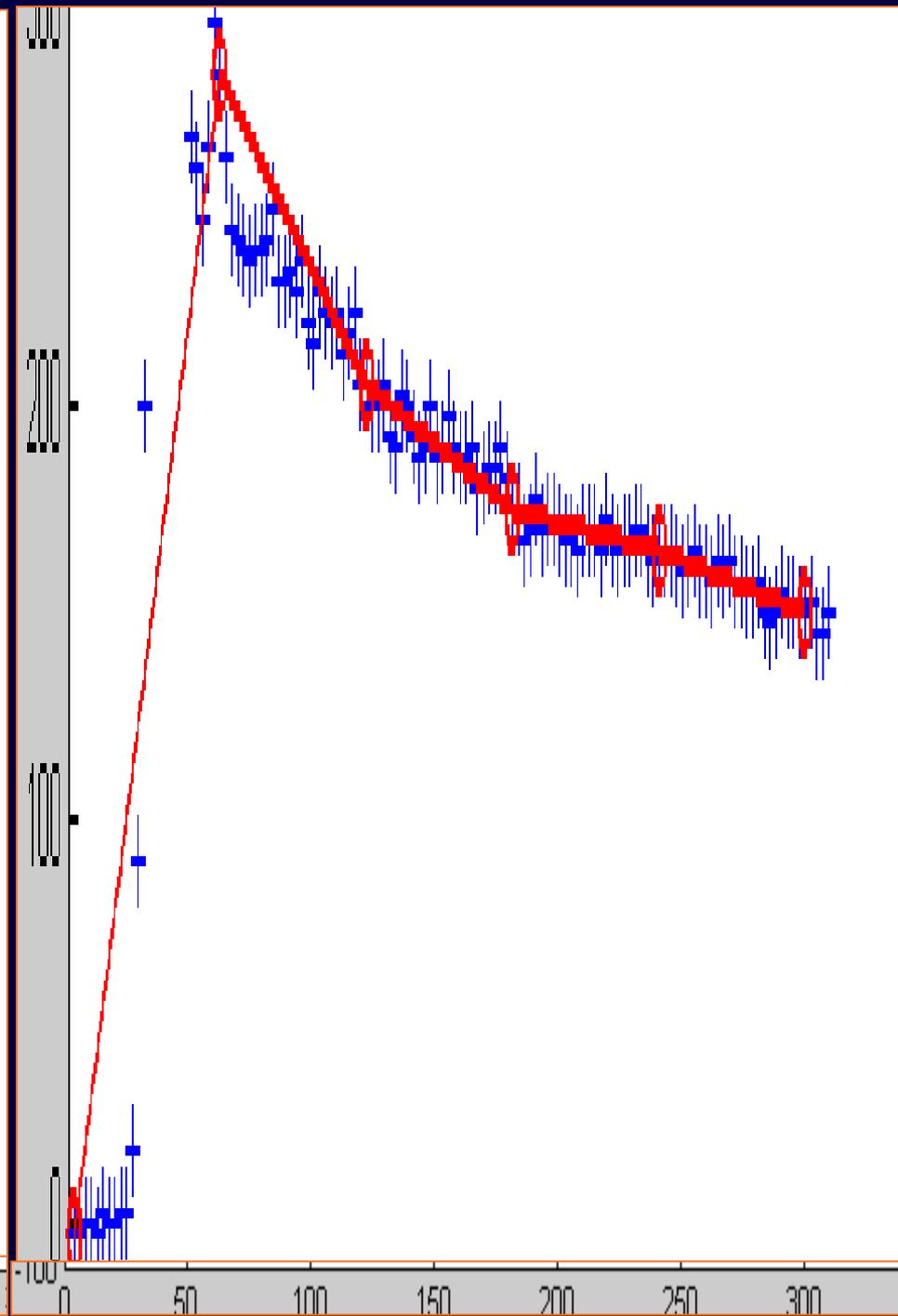
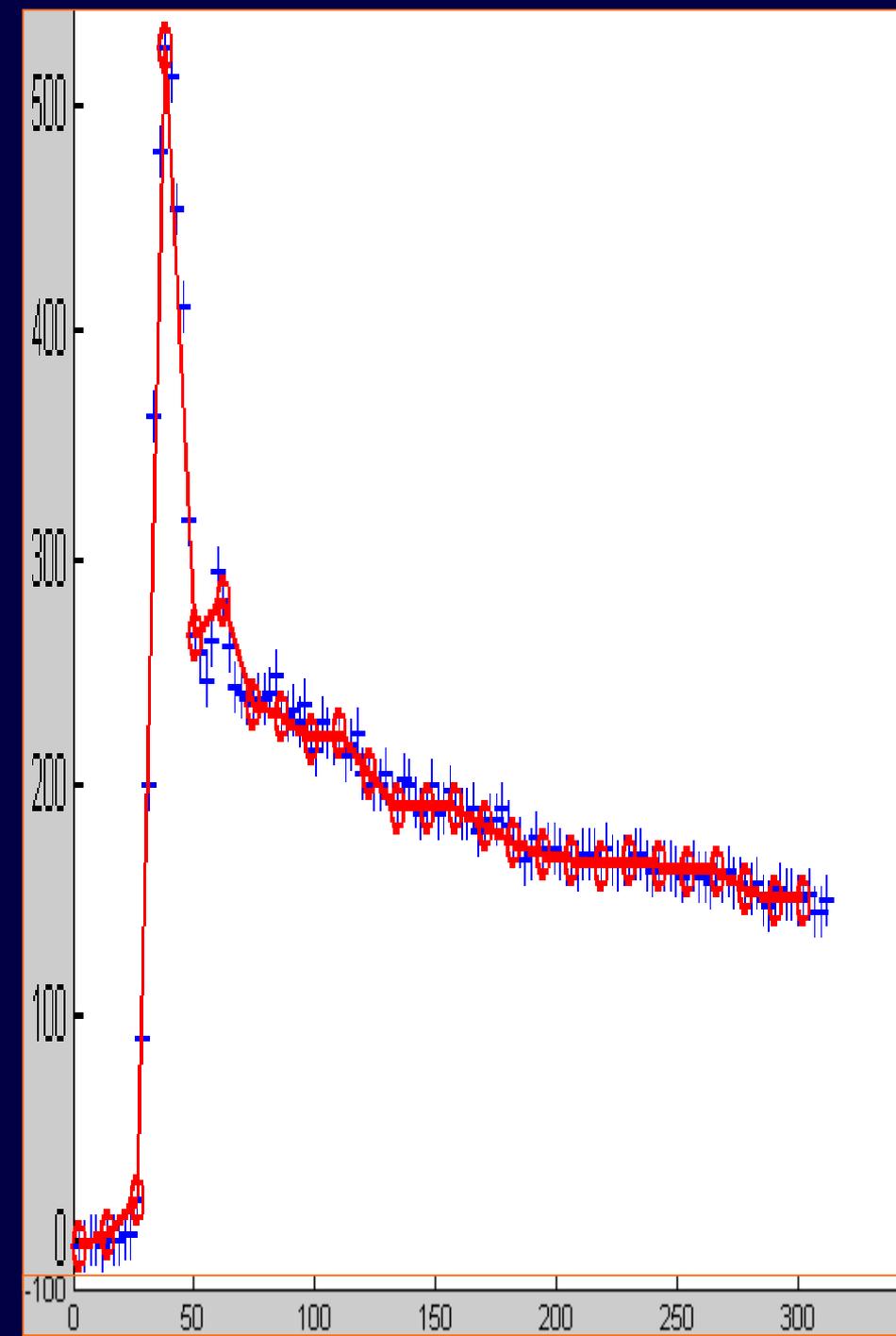
# Acquisition ultra-courte (méthode des pentes)



# Résolution temporelle - échantillonnage

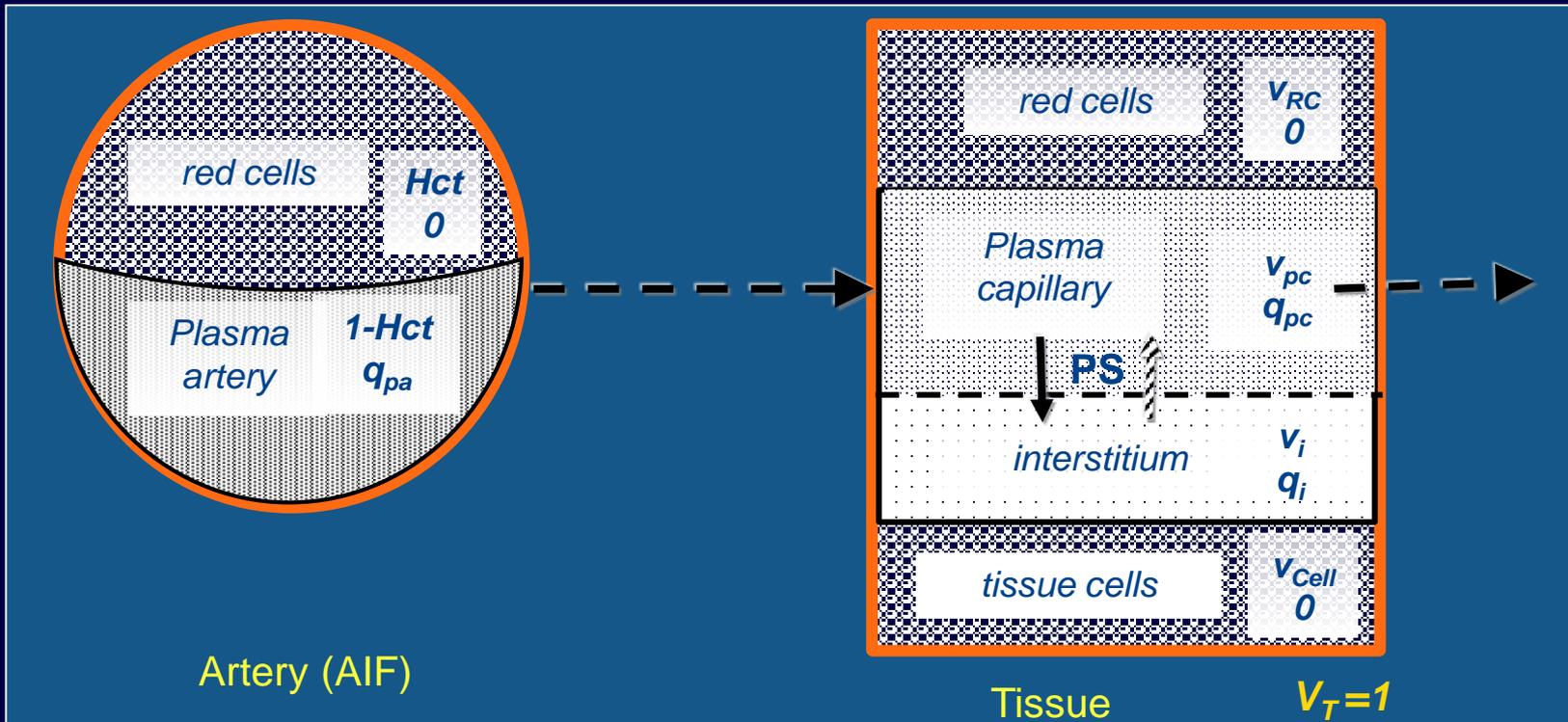






# Faible résolution temporelle

Acquisition longue *Extended Kety* ou *extended Tofts*

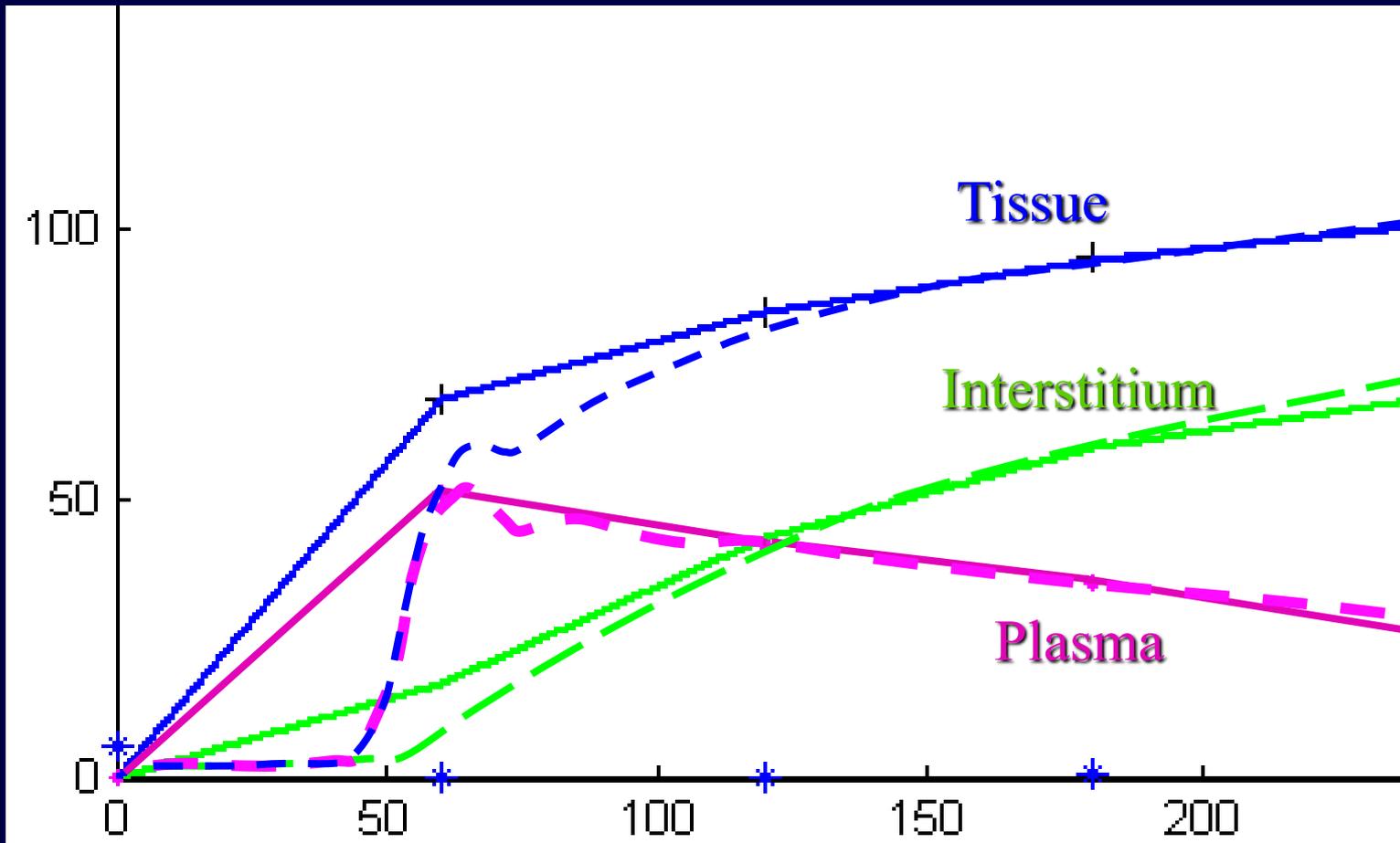


$$q_T = q_{pc} + q_i$$

$$q_{pc}(i+1) = v_p * q_{pa}(i+1) - dt [PS * q_{pc}(i) / v_{pc} + PS * q_i(i) / v_i]$$

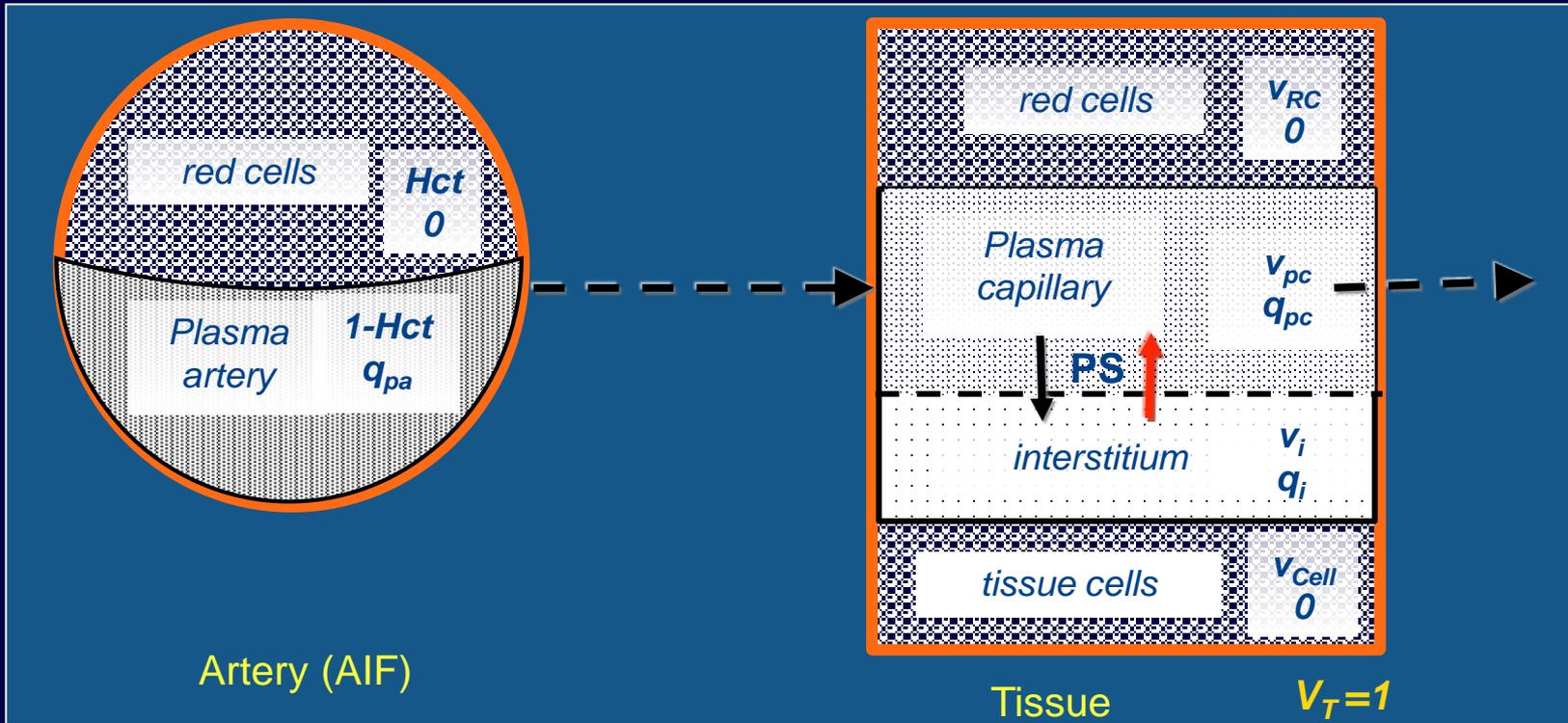
$$q_i(i+1) = q_i(i) + dt [PS * q_{pc}(i) / v_p - PS * q_i(i) / v_i]$$

# Extended Kety



# Faible résolution temporelle

Acquisition moyenne : Patlak

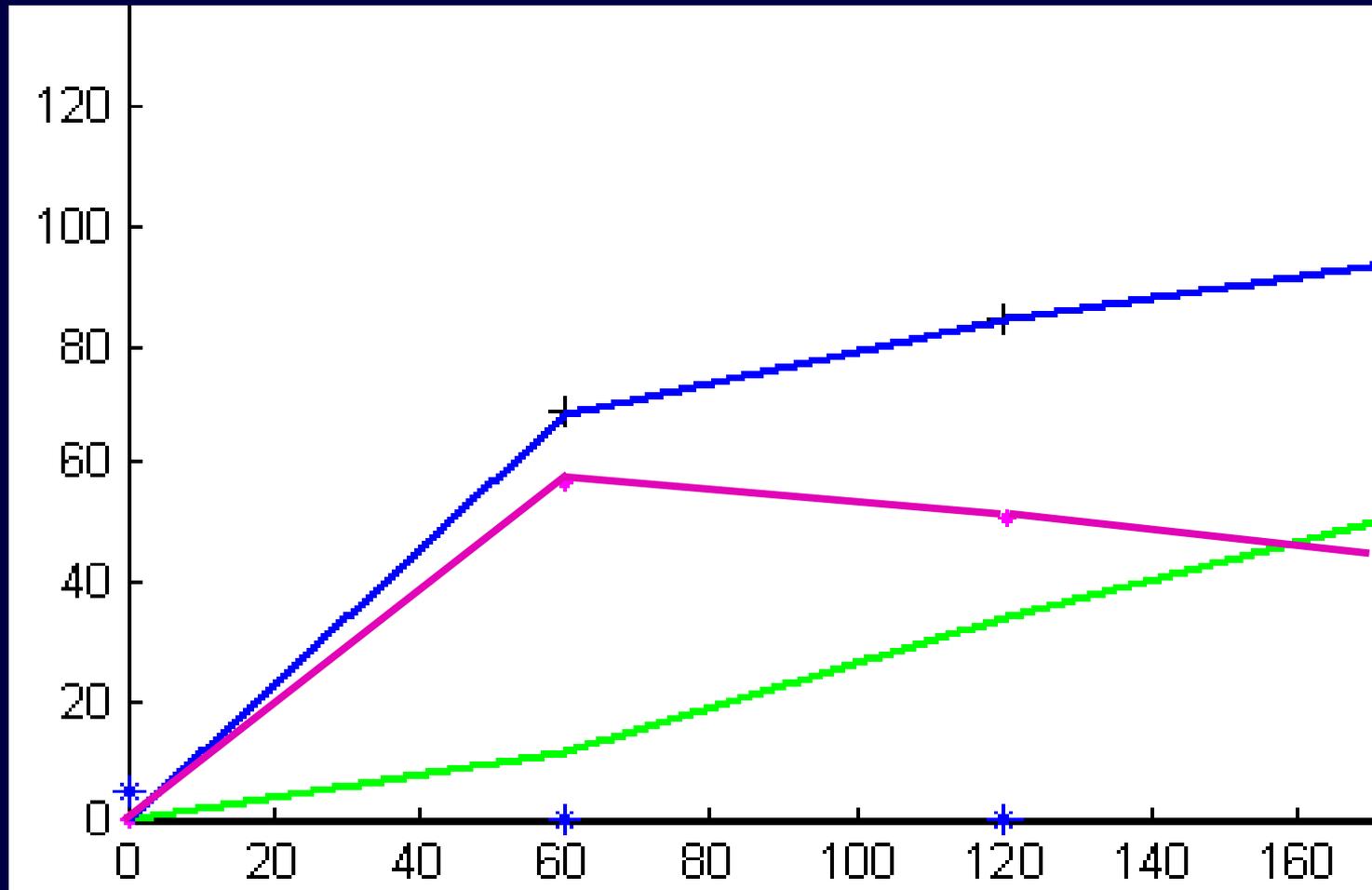


$$q_T = q_{pc} + q_i$$

$$q_{pc}(i+1) = v_p * q_{pa}(i+1) - dt [PS * q_{pc}(i) / v_{pc} - PS * q_i(i) / v_i]$$

$$q_i(i+1) = q_i(i) + dt [PS * q_{pc}(i) / v_p - PS * q_i(i) / v_i]$$

# Patlak



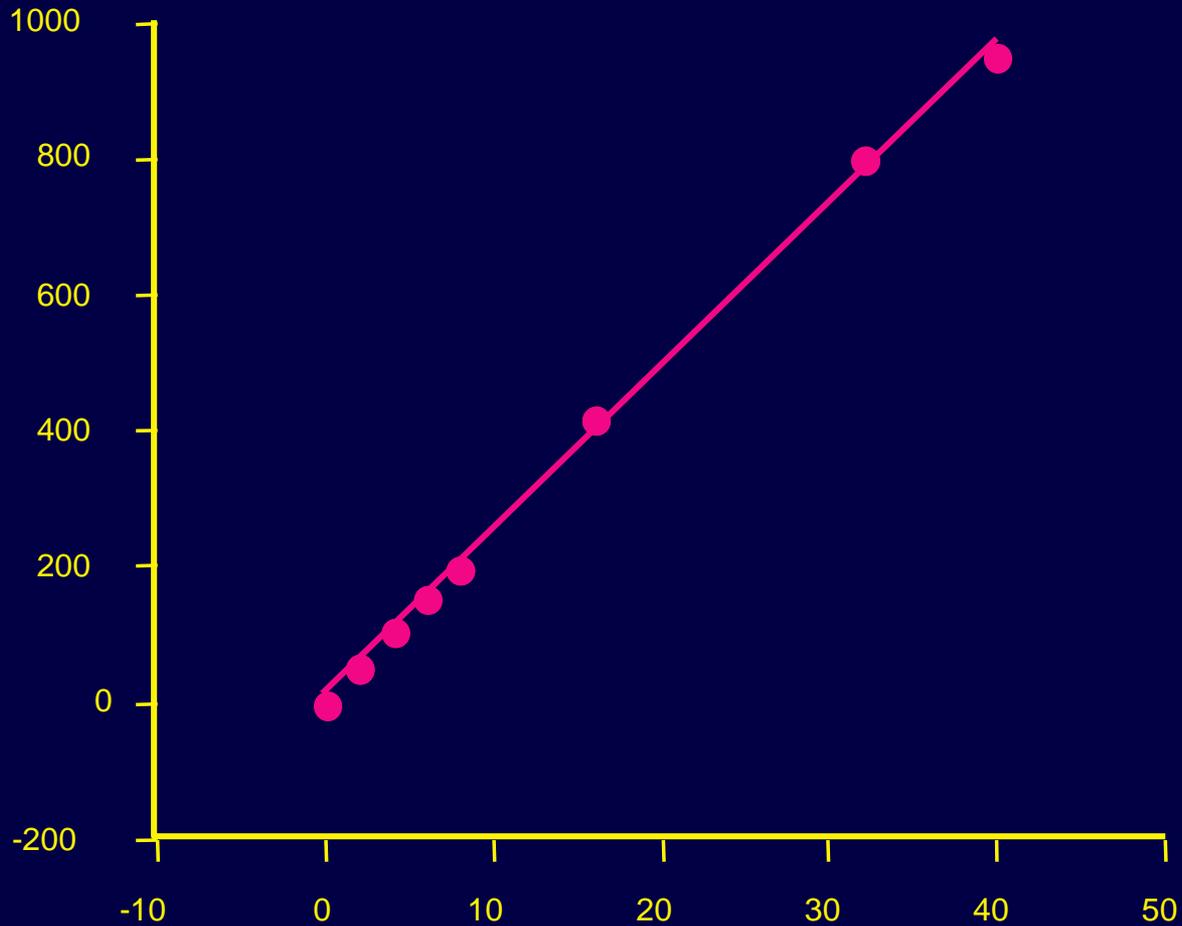
# Théorie unifiée de l'imagerie de la microcirculation

Acquisition / Echantillonnage	Court 60s	Moyen	Long ≥ 600 s
Rapide 1-3 s	FT VB -- -- <i>Premier passage</i>	FT VB PS --	FT VB PS $V_e$ <i>Modèle complet</i>
Moyen			
Lent 30-60s		-- VB PS -- <i>Patlak</i>	-- VB PS $V_e$ <i>Kety étendu</i>

# Relation Signal - Concentration

# Relation

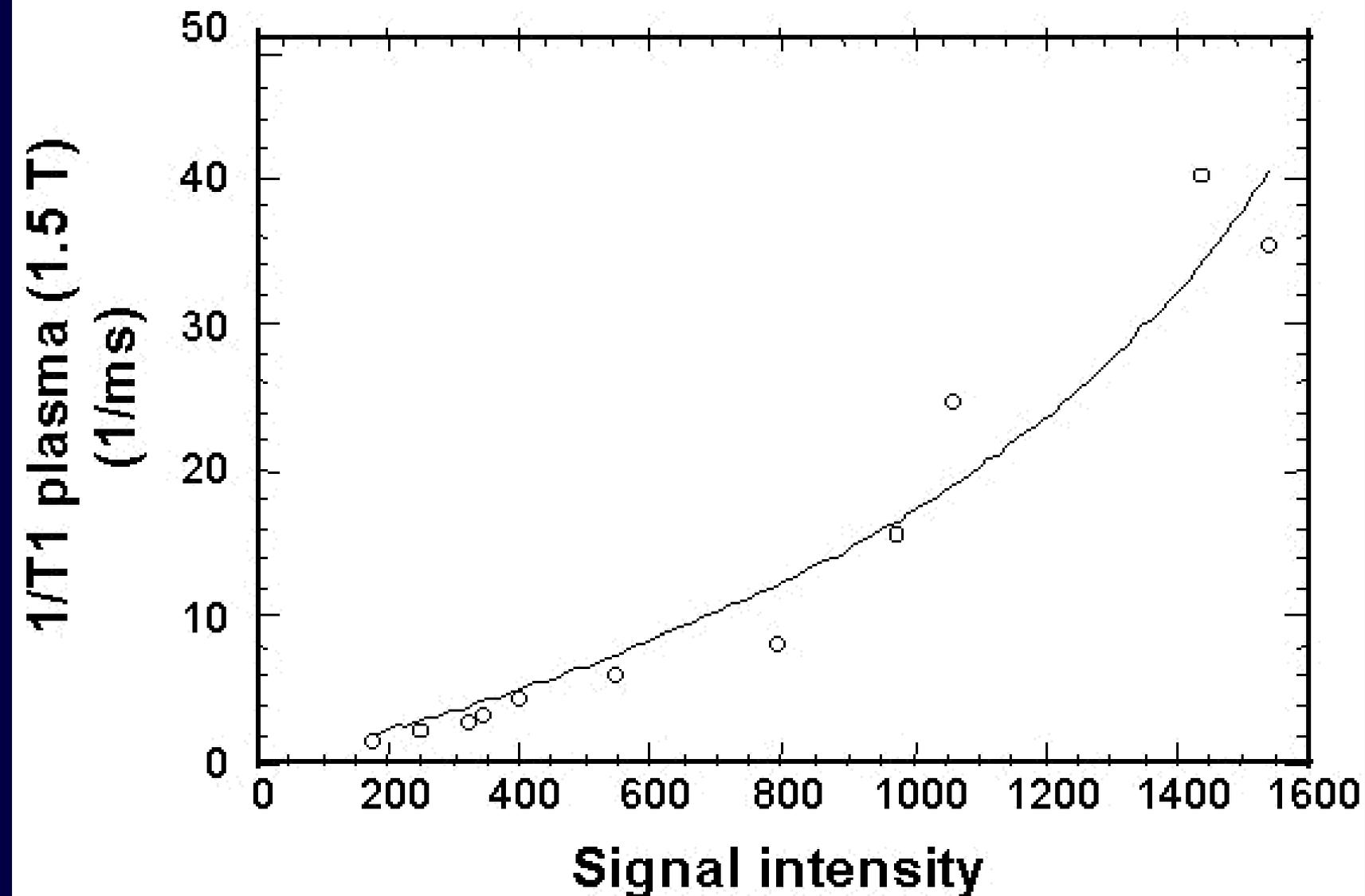
## Attenuation - Agent de Contraste



CA Cuenod

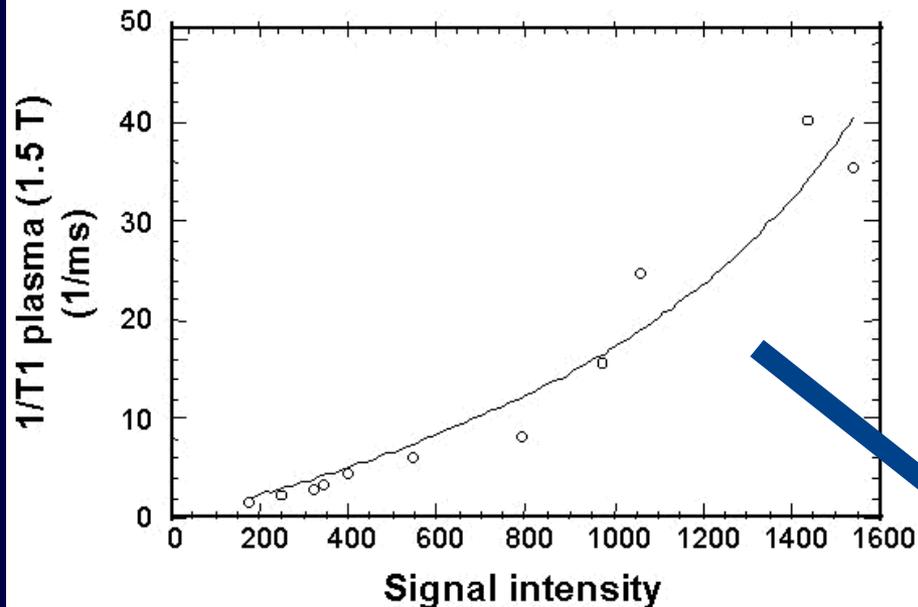
# 1/T1 versus signal intensity

## 2D fast-SPGR & P792

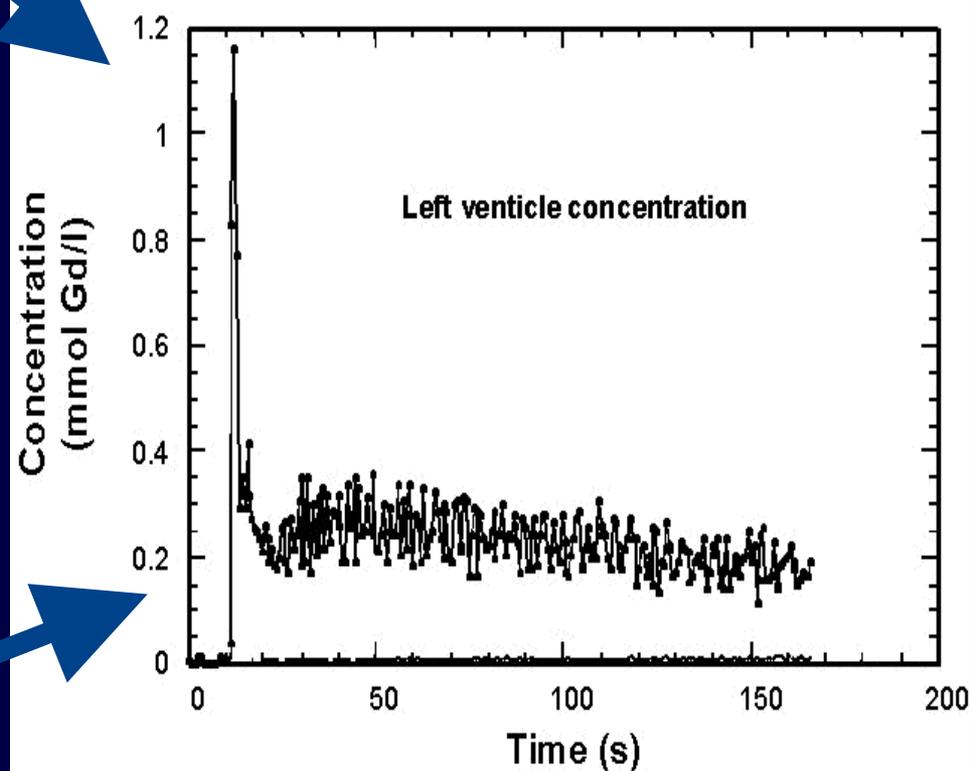


$$IS = m_0 \cdot \sin \alpha \cdot \exp\left(-\frac{TE}{T2^*}\right) \frac{1 - \exp\left(-\frac{TR}{\frac{1}{T1_0} + r1 \cdot C}\right)}{1 - \cos \alpha \cdot \exp\left(\frac{TR}{\frac{1}{T1_0} + r1 \cdot C}\right)}$$

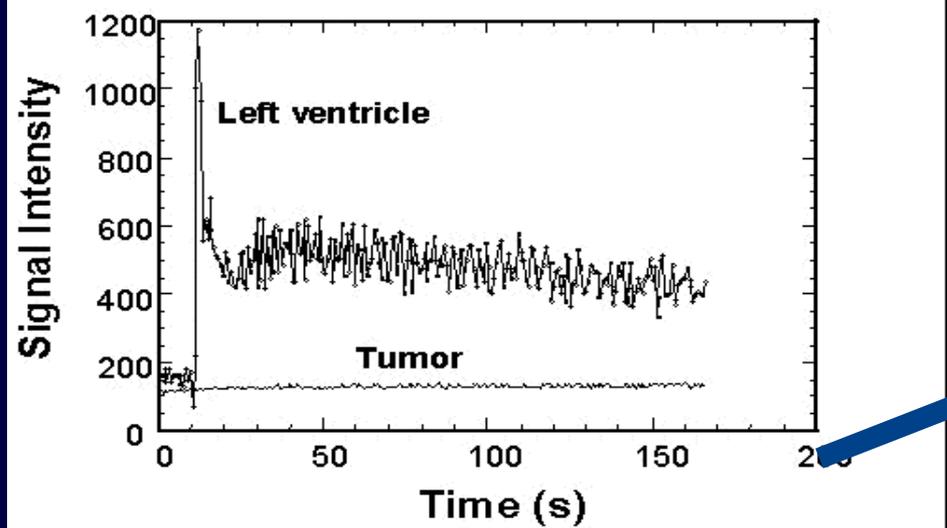
### 1/T1 versus signal intensity 2D fast-SPGR & P792



### Arterial concentration at First Pass 2D Fast SPGR – P792



### Enhancement of Signal intensity at the first pass



# Effet T1 ou T2\* ?

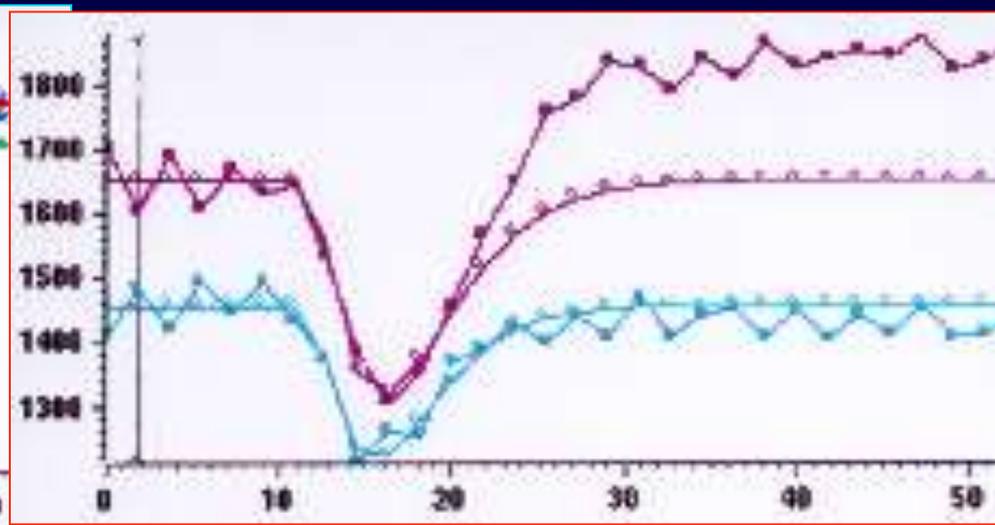
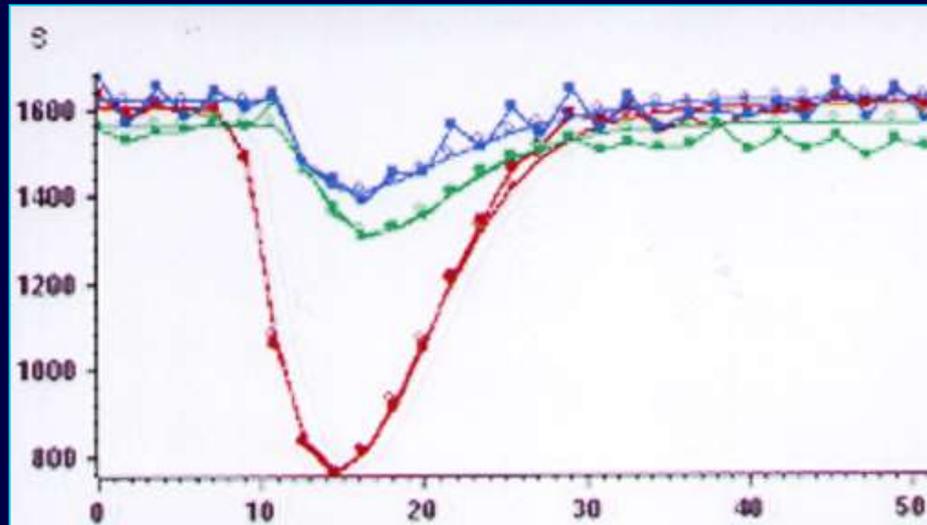
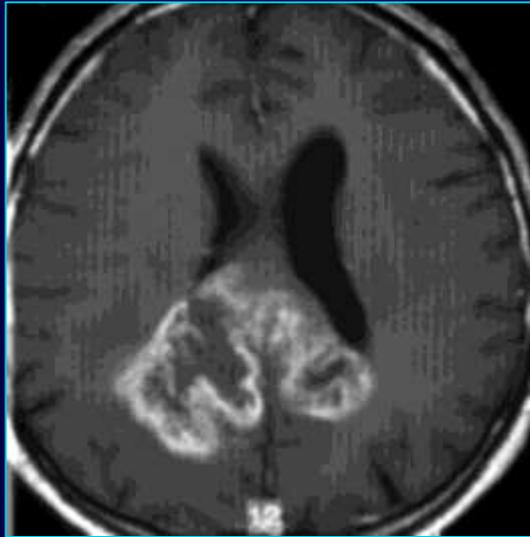
## Effet T1

- Perméabilité ++
- Perfusion difficile
- Courbe de conversion
- Faible S/B

## Effet T2\*

- Que la perfusion
- Nécessité  $PS \pm 0$ 
  - BHE
  - Macromol. Particule
- Relation «simple» du signal

# Gliome vs. Lymphome du splénium

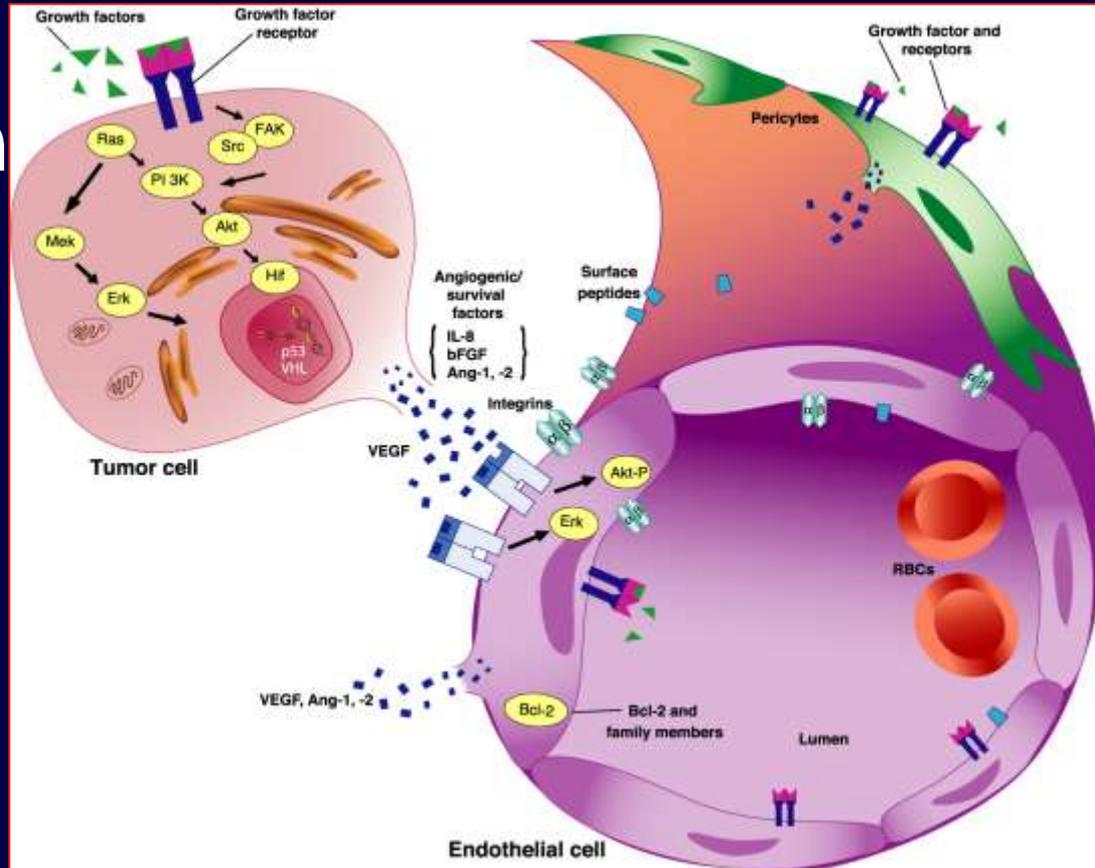


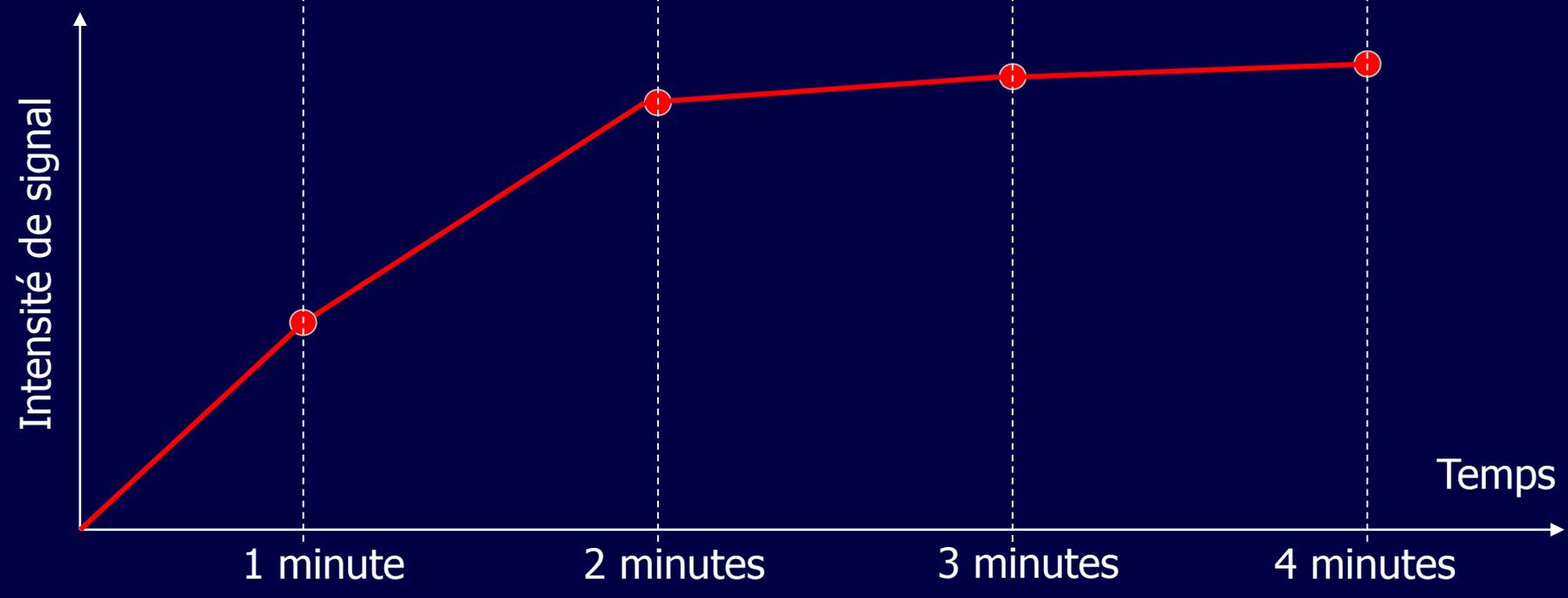
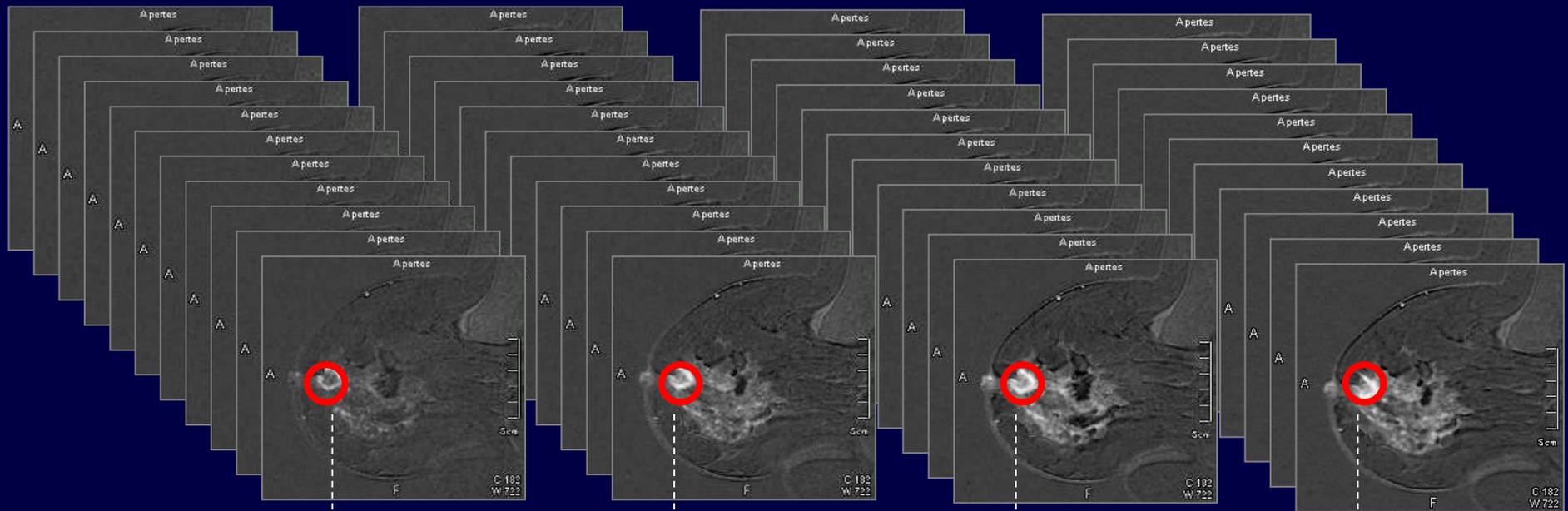
*Sylvie Legrand Grenoble*

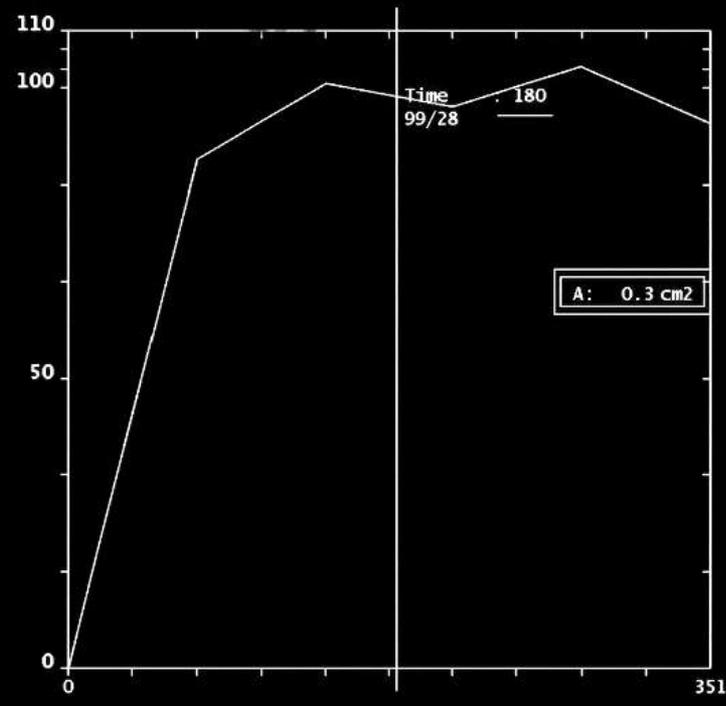
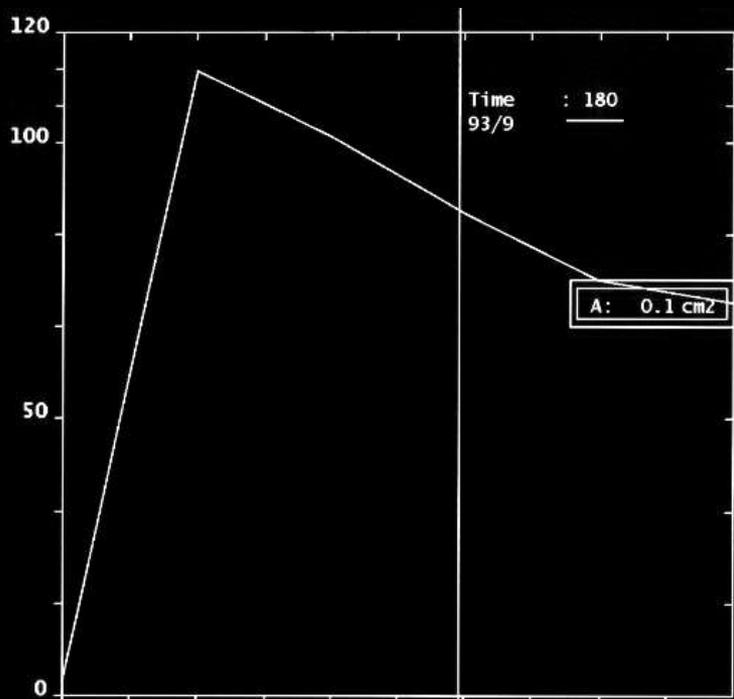
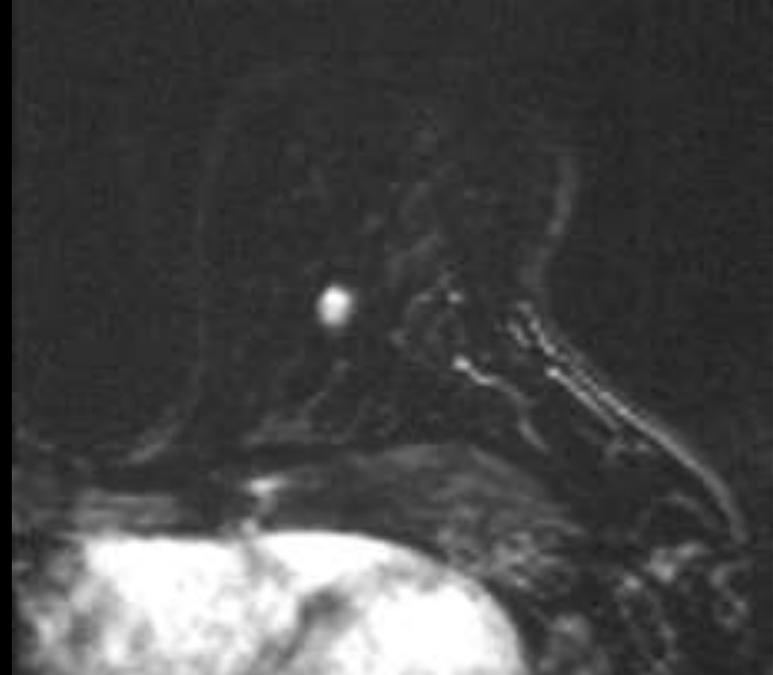


# Néovascularisation tumorale

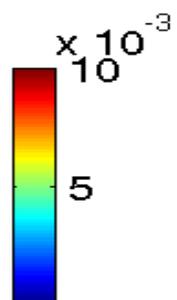
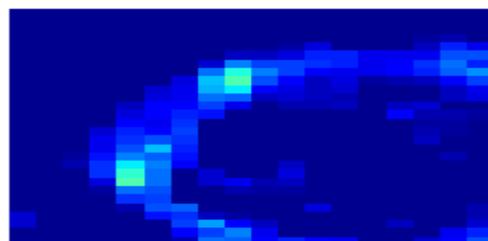
- Support de la croissance
- Médiée par le **VEGF**
- Cible thérapeutique



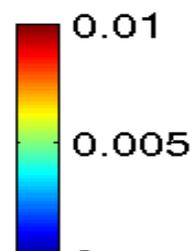
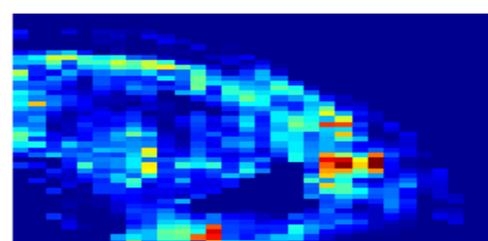




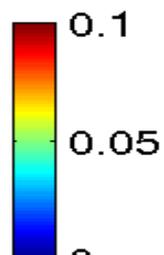
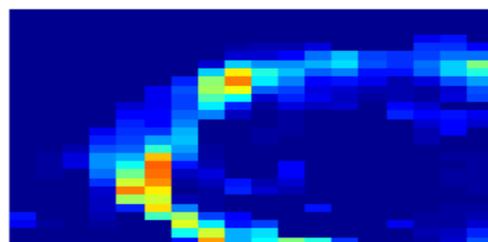
permea. / 4 param



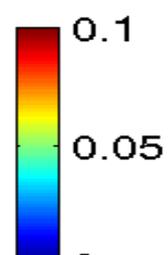
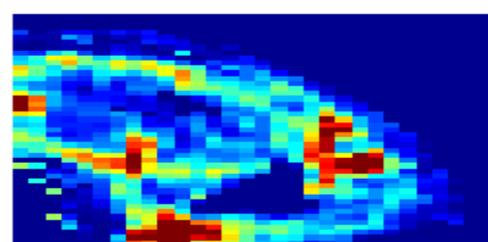
permea. / 4 param



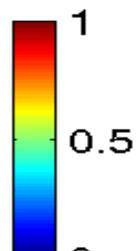
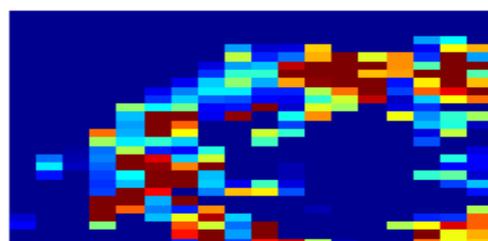
frac cap / 4 param



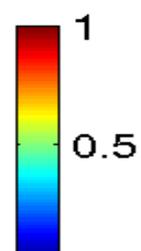
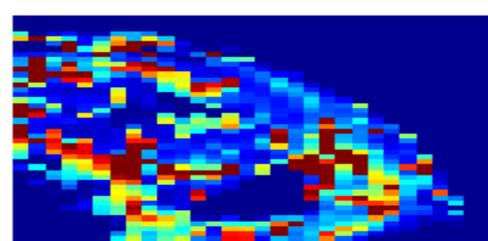
frac cap / 4 param



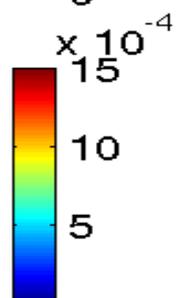
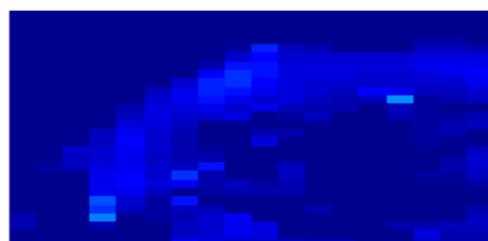
frac inter / 4 param



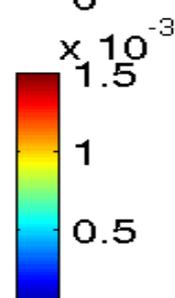
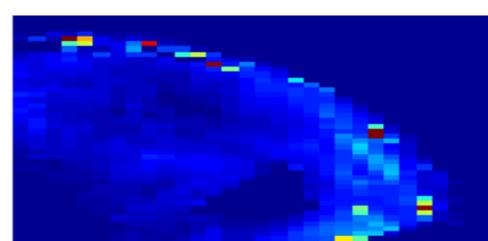
frac inter / 4 param



perfusion / 4 param



perfusion / 4 param



treated

placebo

# Résumé

- Imagerie de perfusion et perméabilité DCE-MRI
- Analyse qualitative ou quantitative
- En quantitatif nécessité de ligne de base et de correction du signal et d'un modèle mathématique
- Nécessité d'une bande de saturation en amont
- Dépend de la résolution temporelle et de la durée d'observation
- Acquisition en pondération T1 en corps entier
- Acquisition en pondération T2\* en neurologie
- Application en pathologie ischémique et tumorale

# Autres méthodes de mesure de la perfusion

- Diffusion : technique multi b (IVIM)
- Arterial Spin Labelling : ASL
- Méthode indirecte : BOLD

