

Module Image

IMAGERIE MEDICALE

Dr Denis Hoa



IMAIOS SAS
Montpellier – France
denis.hoa@imaios.com



CHU Lapeyronie



LIRMM

Imagerie Médicale

1. Acquisition des images médicales
Techniques d'imagerie médicale moderne
2. Evaluation diagnostique et imagerie médicale
Valeurs diagnostiques d'un test
Seuil et discrimination en classes : courbes ROC
3. Traitement des images médicales

Module Image : Imagerie médicale

TECHNIQUES D'IMAGERIE MEDICALE

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LIRMM

Techniques d'imagerie médicale moderne

- Echographie
- TDM
- IRM

Format des images médicales

- DICOM

Pourquoi plusieurs modalités d'imagerie ?

Propriétés physiques différentes

US : Echographie

RX : Radiographie, Tomodensitométrie

RMN : Imagerie par Résonance Magnétique

Pourquoi plusieurs modalités d'imagerie ?

Accessibilité et Portabilité



Echographie



IRM



IRM / TDM ...

Pourquoi plusieurs modalités d'imagerie ?

Effets délétères potentiels

Principe de précaution

Eviter répétition des risques

Rapport bénéfice / risque

Pourquoi plusieurs modalités d'imagerie ?

Vécu du patient



Pourquoi plusieurs modalités d'imagerie ?

Coût

Echographe

30 - 150 K€

Scanner

500 – 1 M€

IRM

1,5 – 4 M€

Echographe

~ 80 €

Scanner

~ 150 €

IRM

~ 300 €

Indications typiques des différentes modalités

Rayons X

Radiographies : fractures

Radioscopie : interventionnel

TDM : Crâne, TAP

Ultrasons

Obstétrique

Cardiovasculaire

Mobile au lit du patient

IRM

Tissus mous

Neuroimagerie

Imagerie fonctionnelle

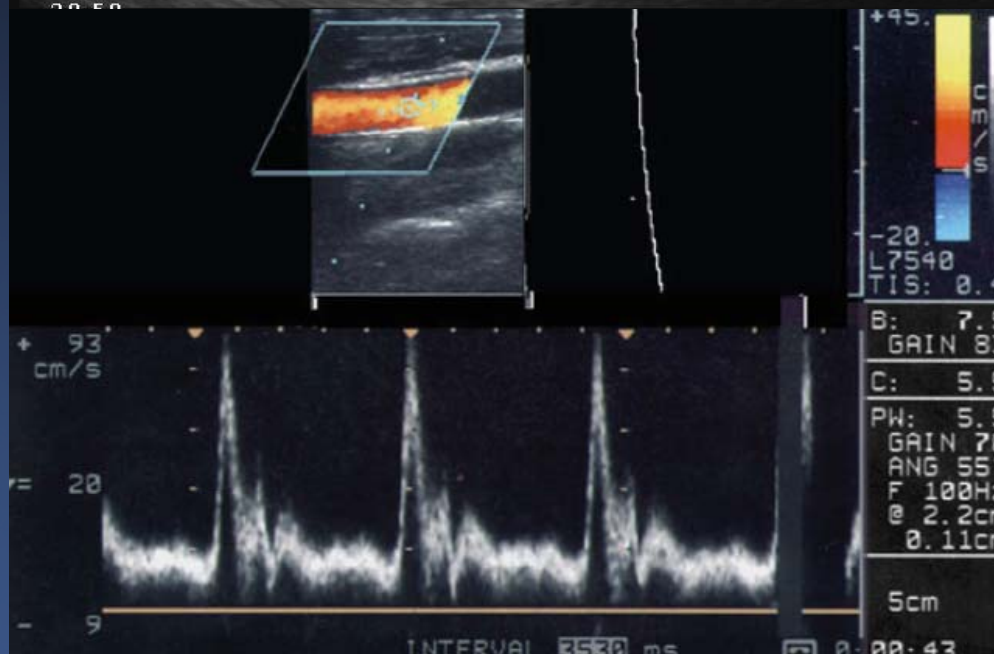
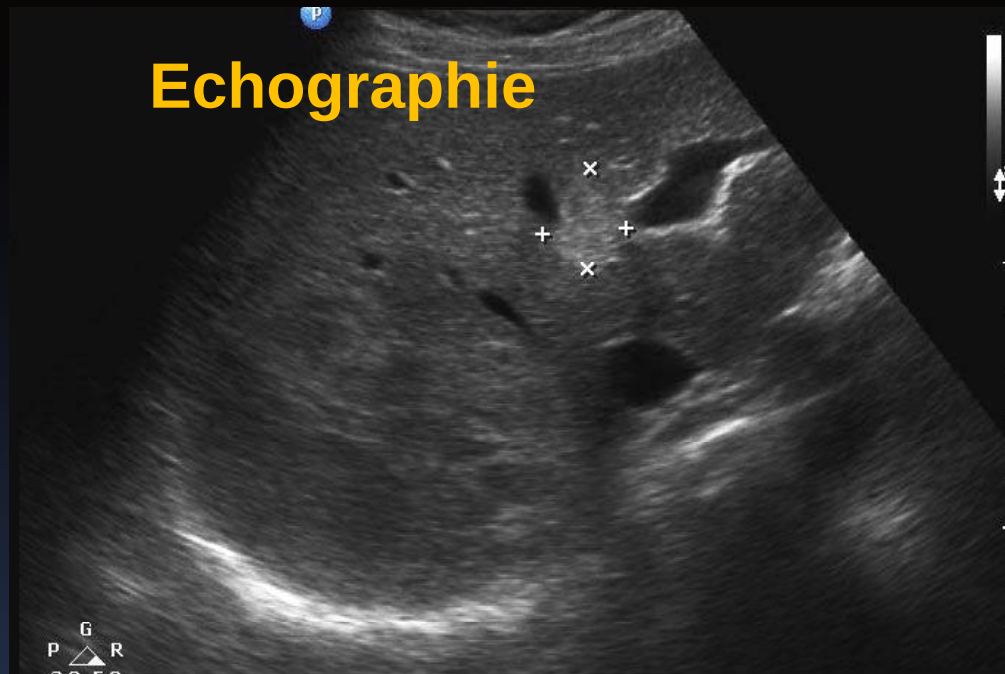
Echographie

TDM

IRM

DICOM

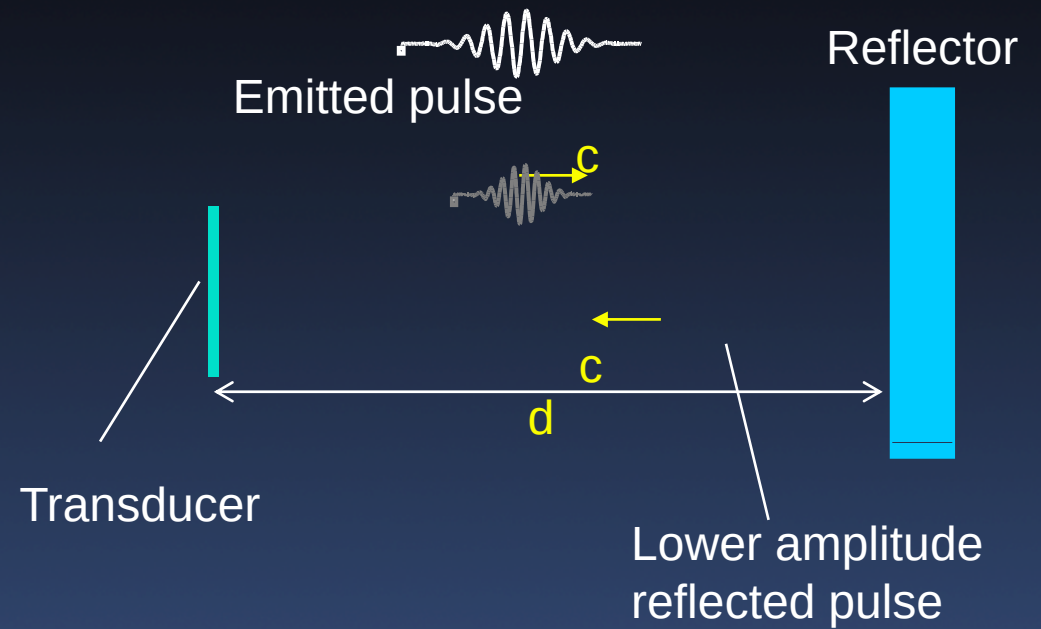
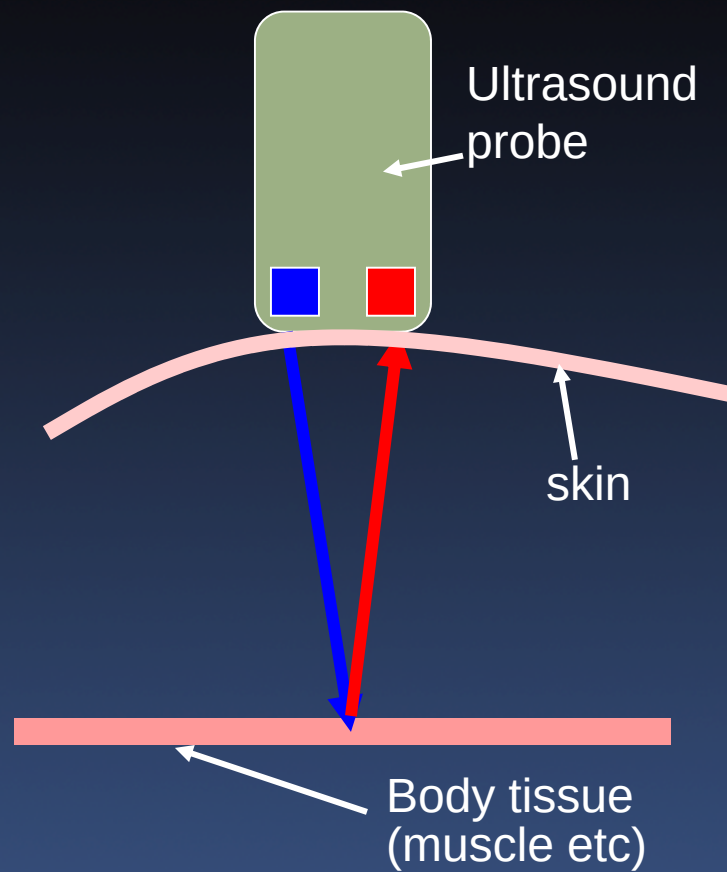
Echographie



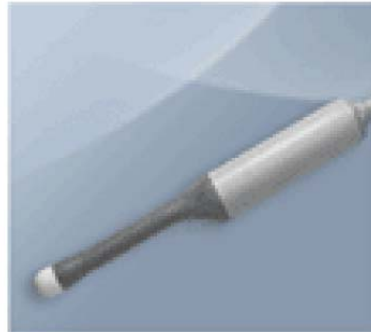
Echographie



Principes physiques



Sondes

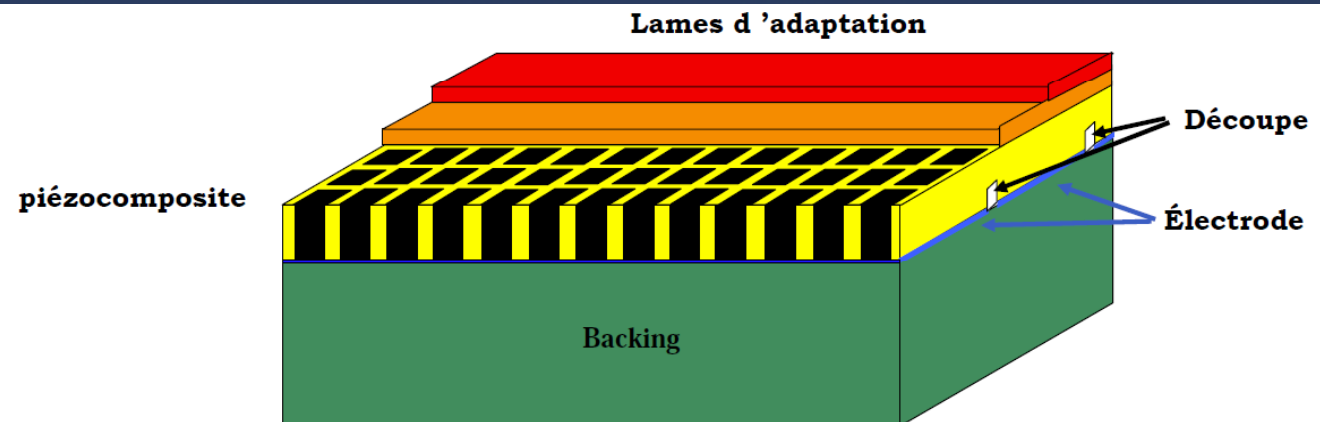
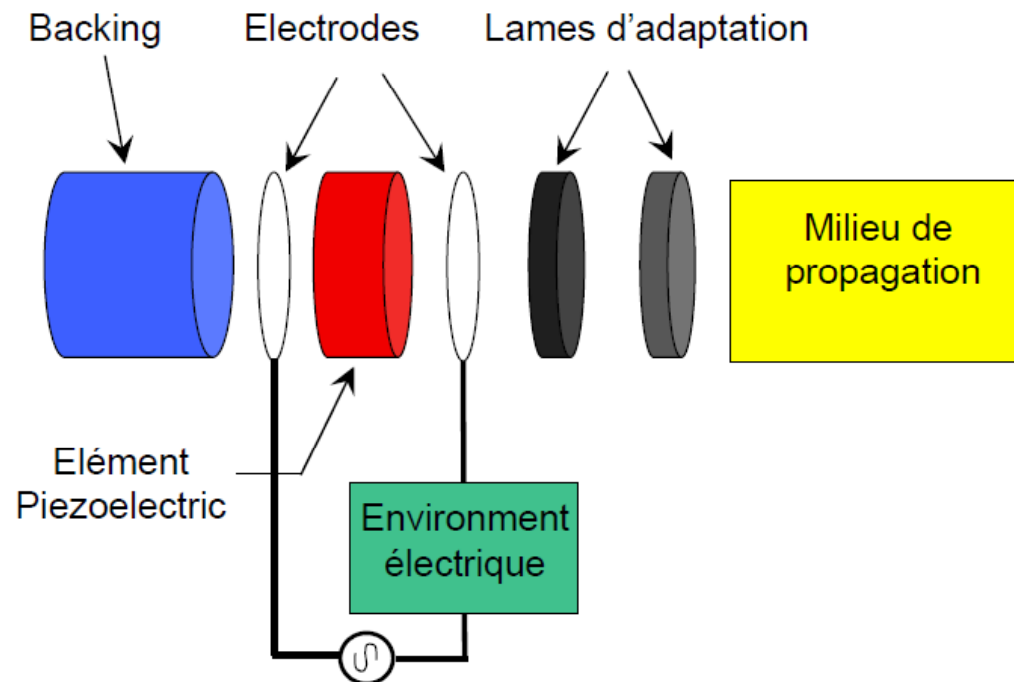


ABDOMEN(VA4-7)

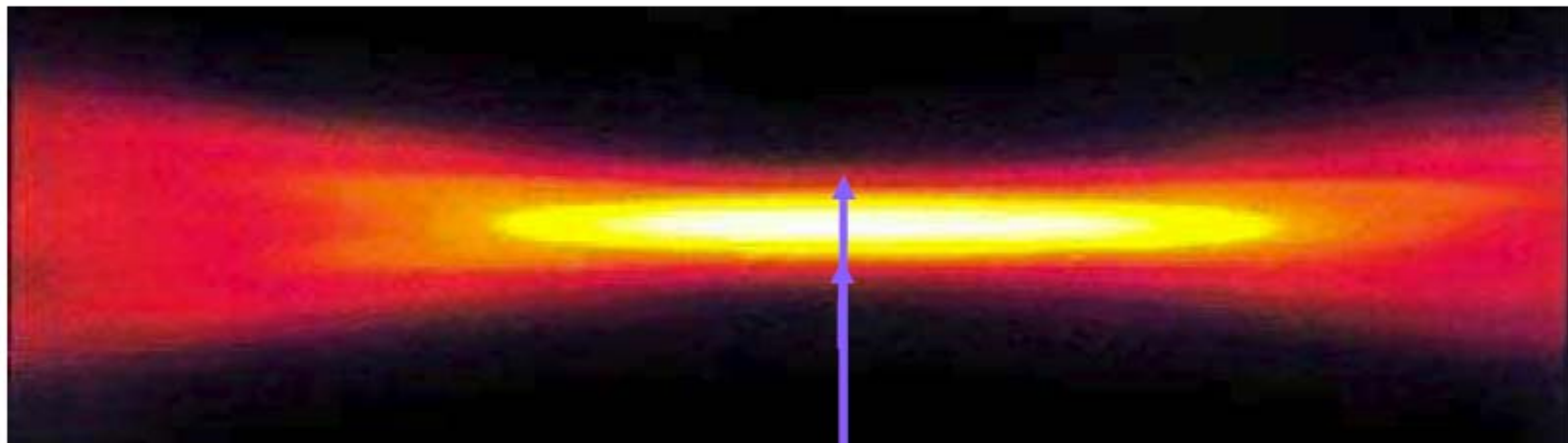
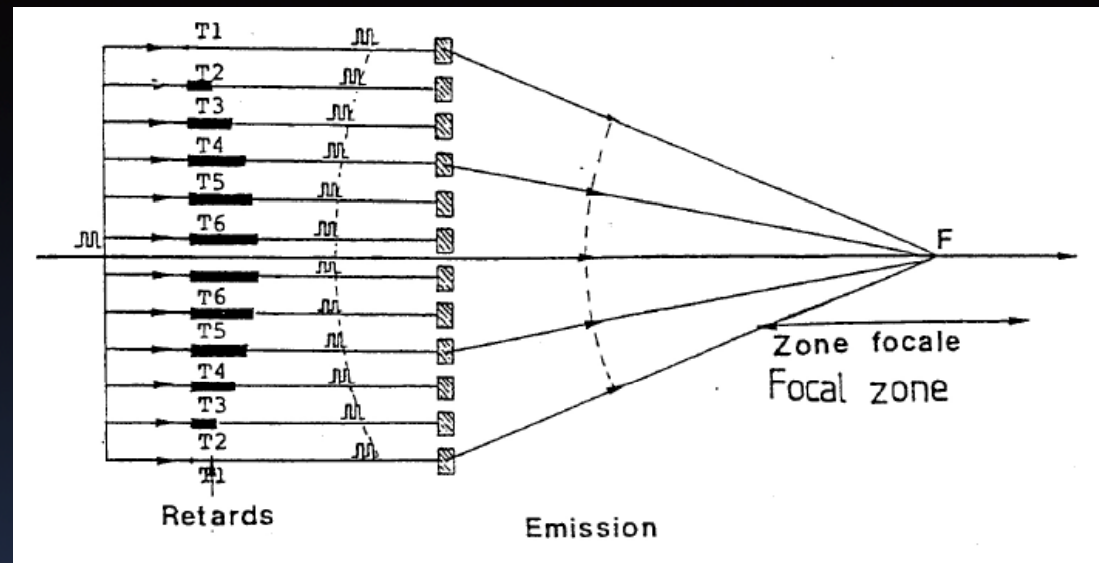
TRANSVAGINAL(VA5-88)

LINEAR(VN6-12)

Sondes

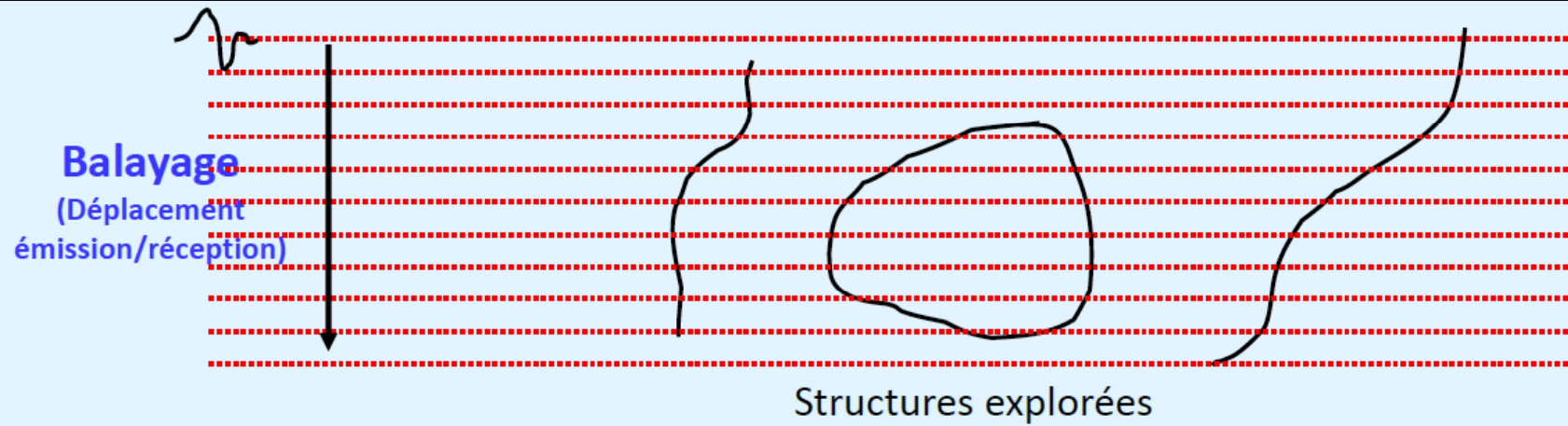


Focalisation

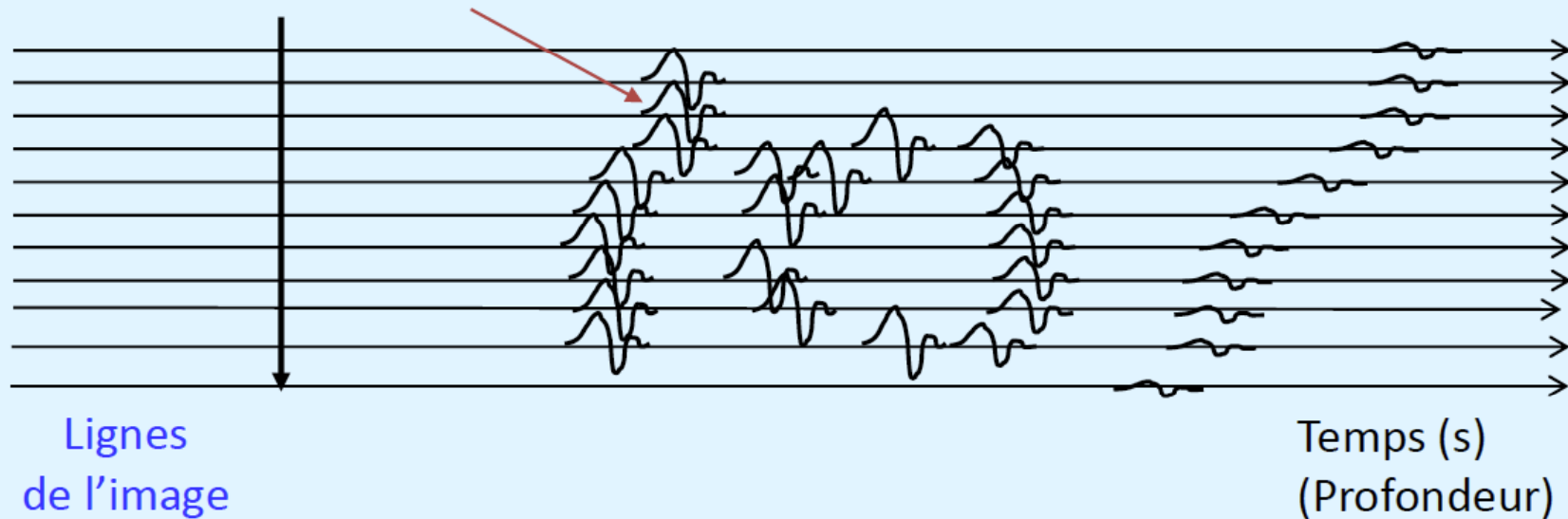


R lat

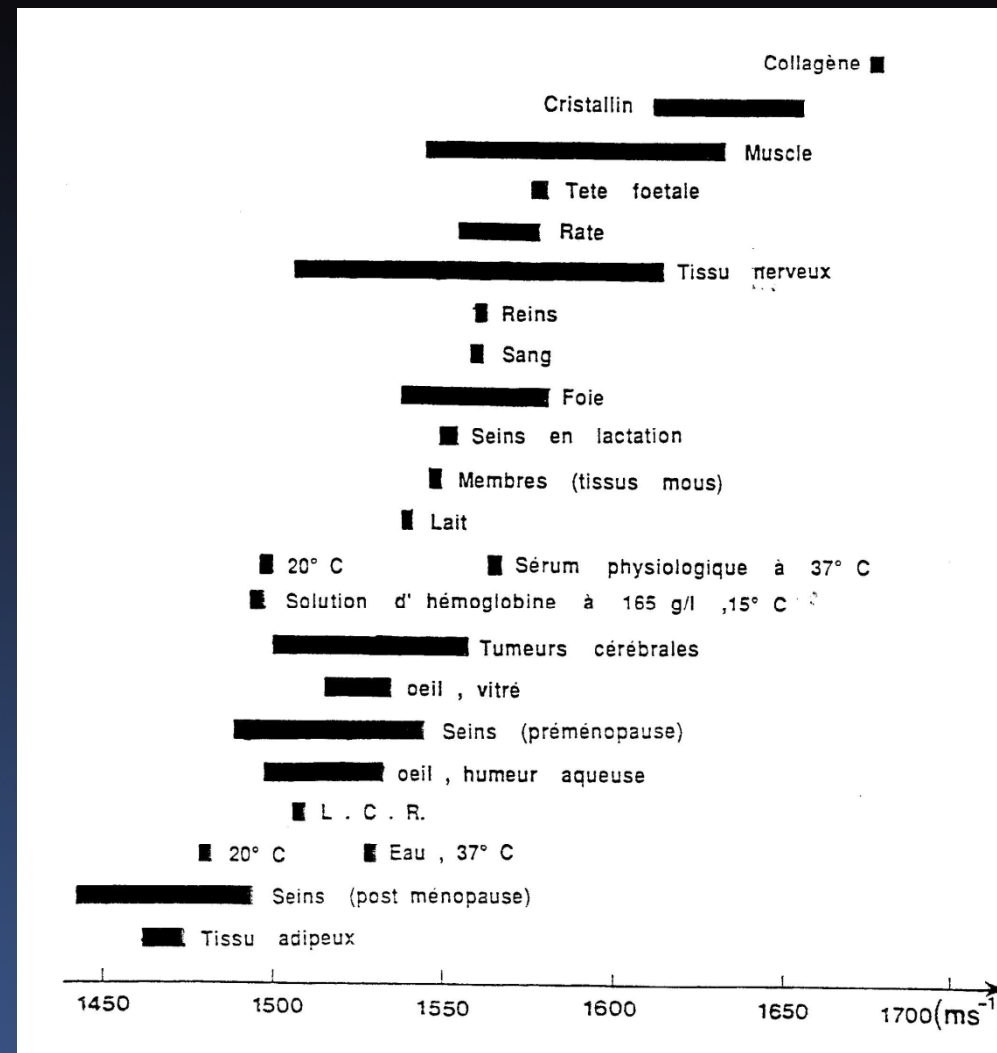
Construction de l'image



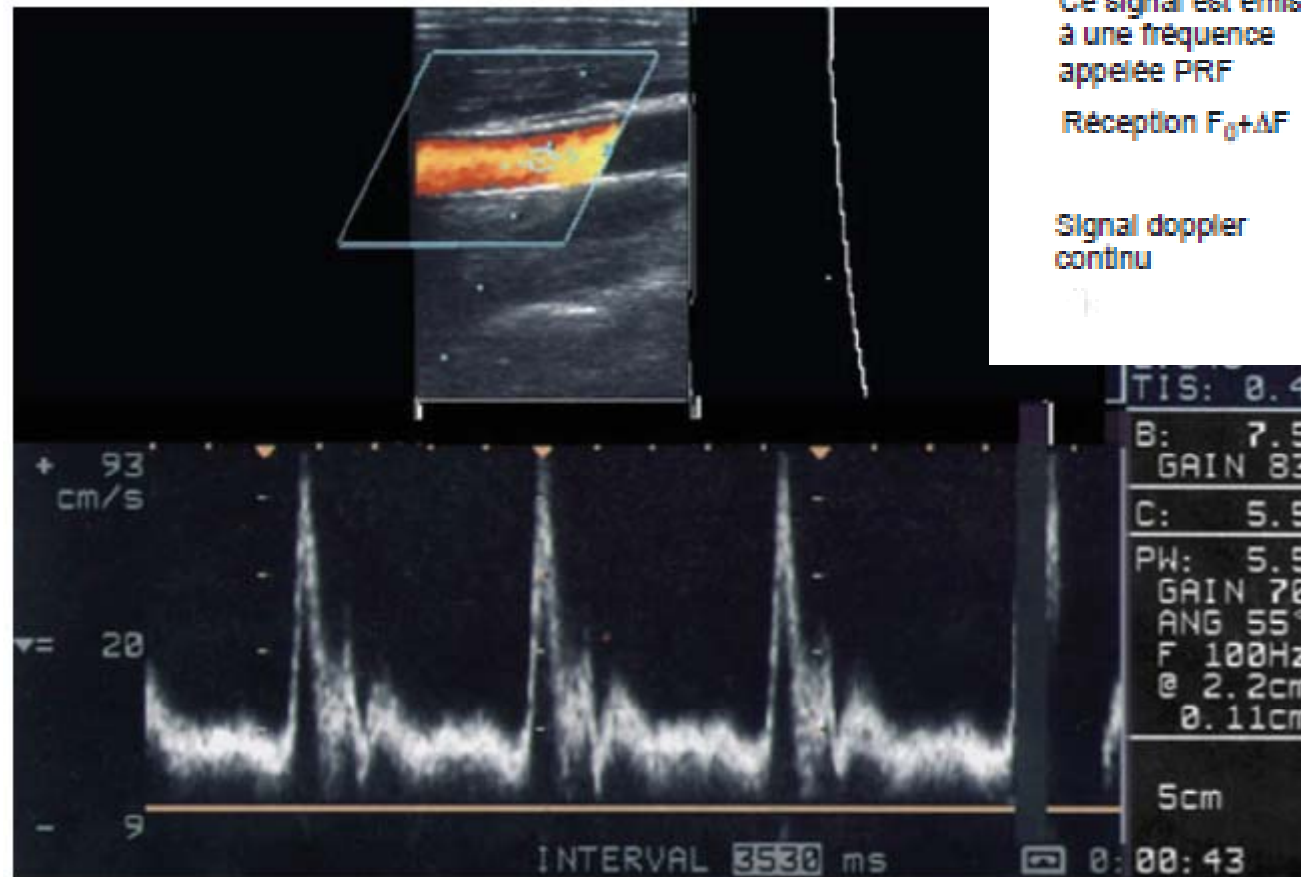
Amplitude des échos



Vitesses de propagation dans le corps humain



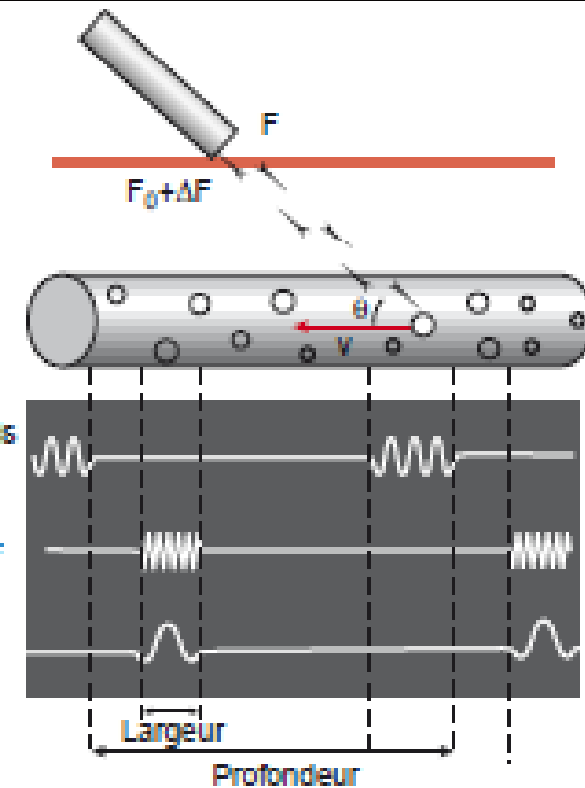
Doppler et flux



Émission F_0
Ce signal est émis
à une fréquence
appelée PRF

Réception $F_0 + \Delta F$

Signal doppler
continu



Echographie

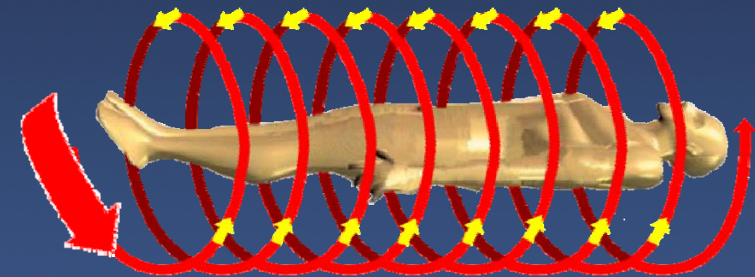
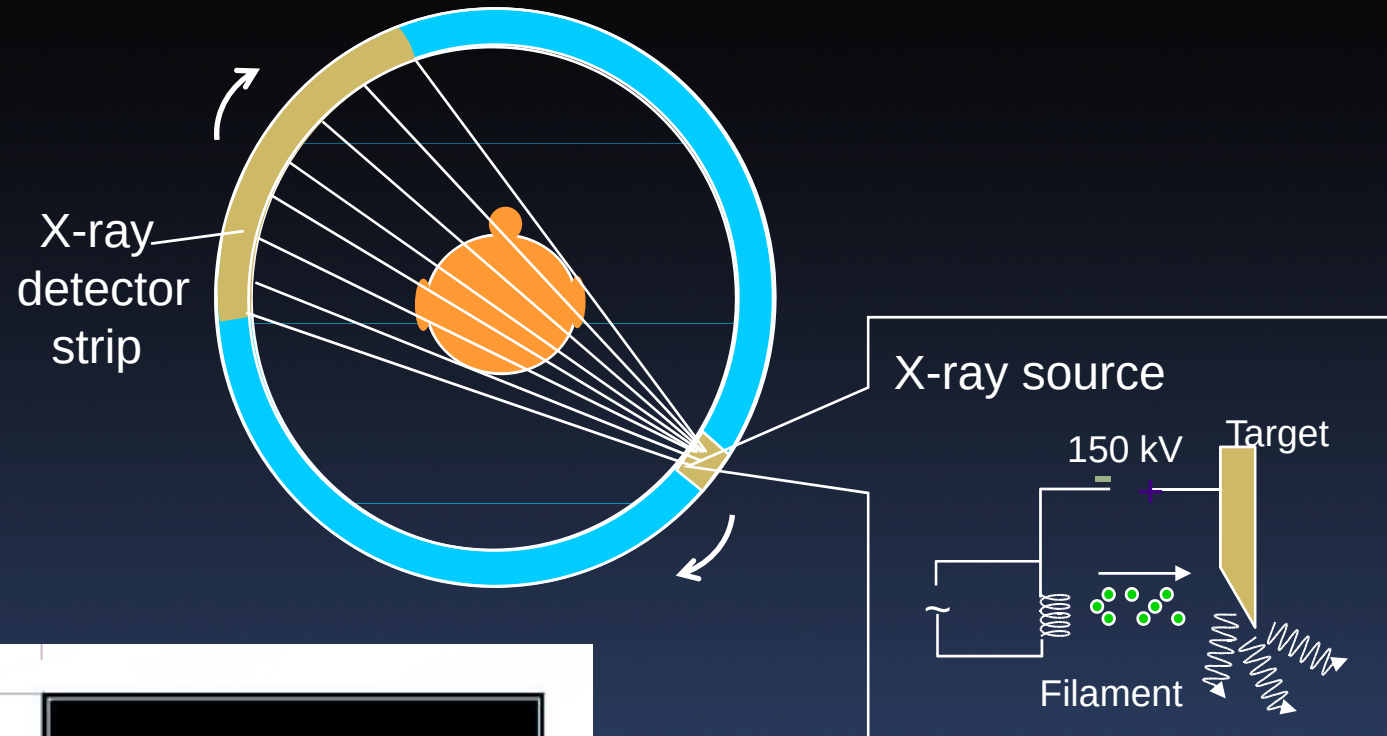
TDM

IRM

DICOM



Acquisition hélicoïdale



Acquisitions synchronisées

- *Acquisition séquentielle utilisant le gating en prospectif.*



Interventionnel guidé par TDM



Echographie

TDM

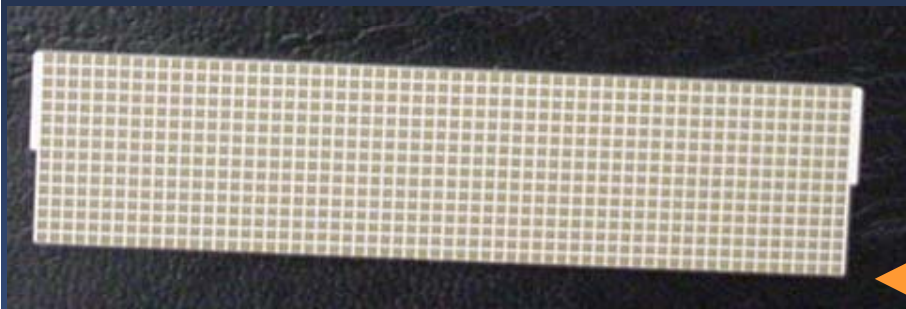
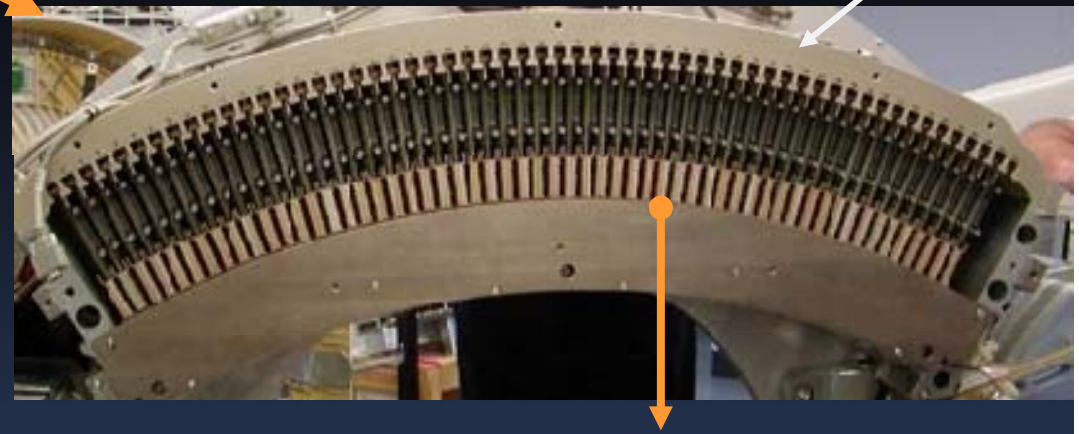
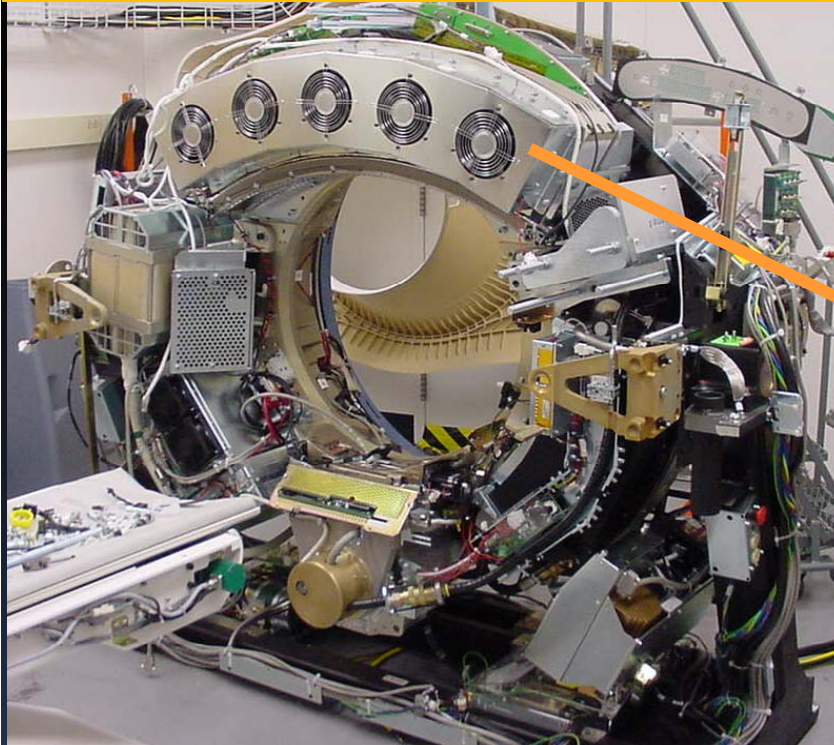
IRM

DICOM

Détecteur 64 coupes GE

statif

Le DAS



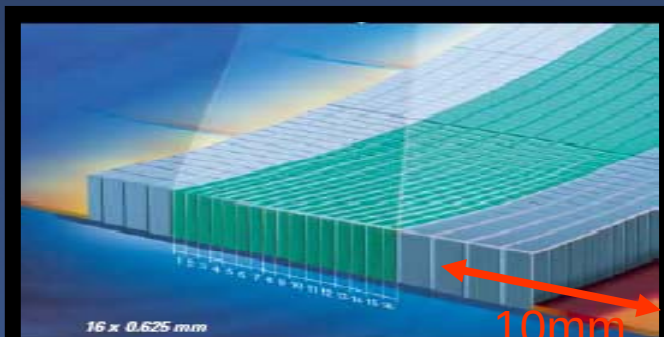
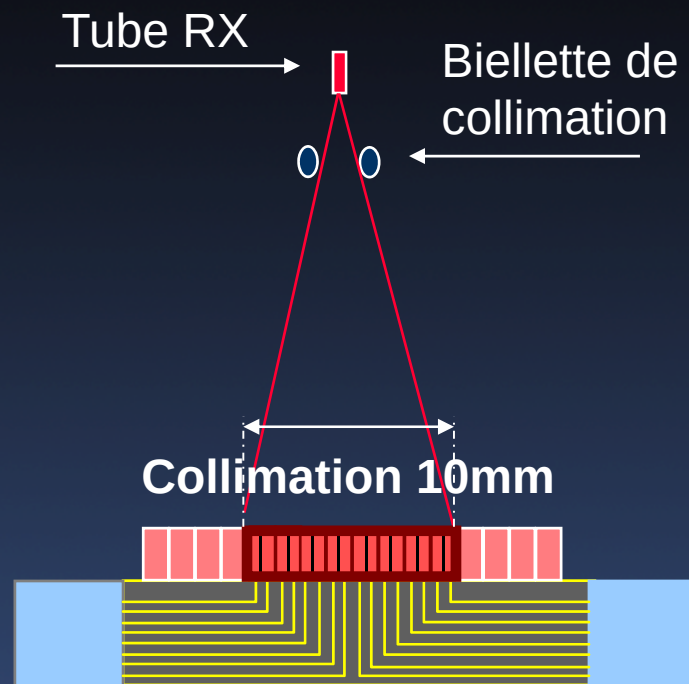
64 cellules de 0,625mm



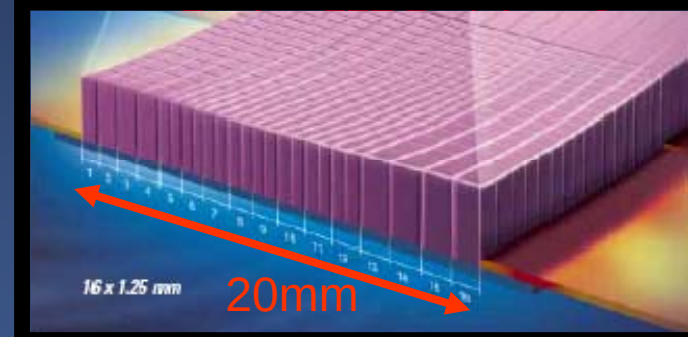
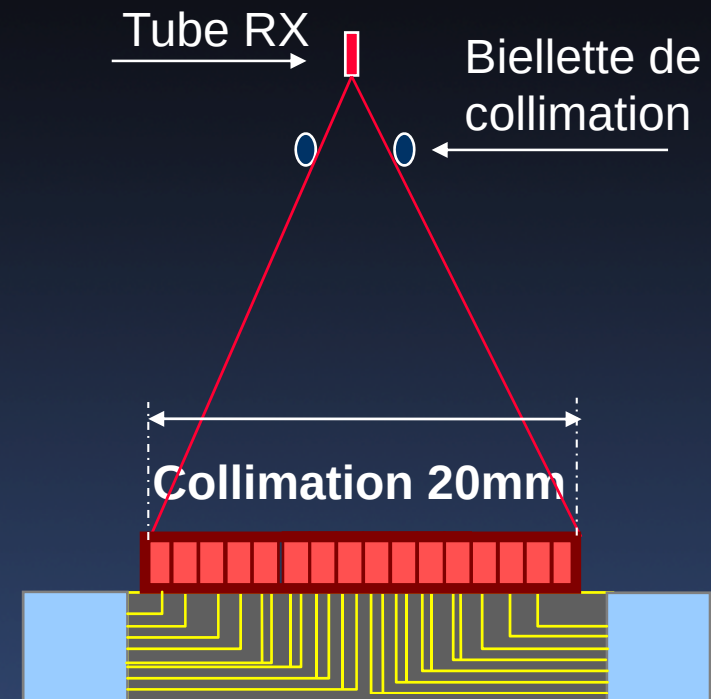
Un élément du détecteur matriciel

Détecteurs et collimation

Configuration 16 x 0,625 mm
Collimation = 10 mm

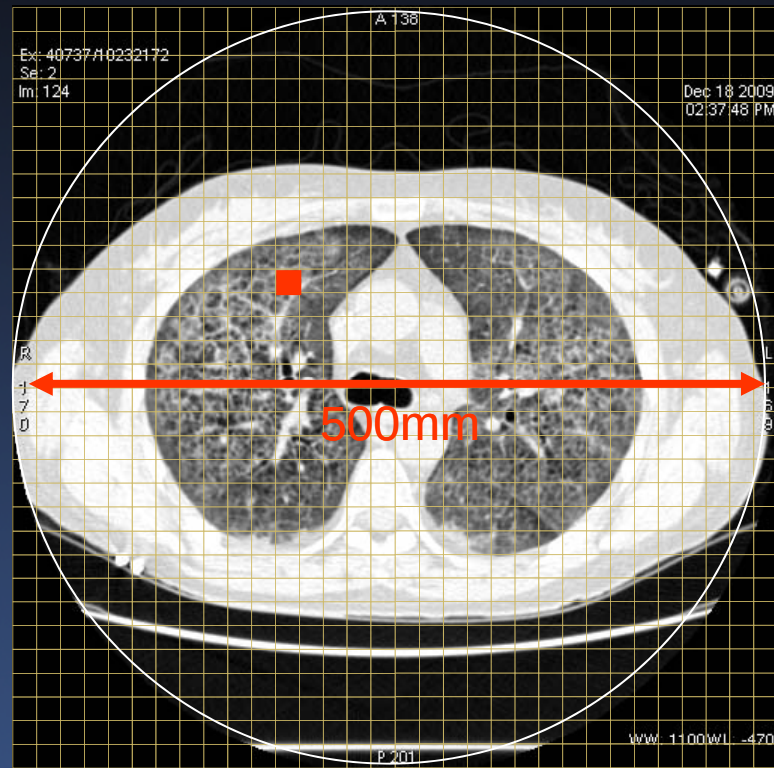


Configuration 16 x 1,25 mm
Collimation = 20 mm

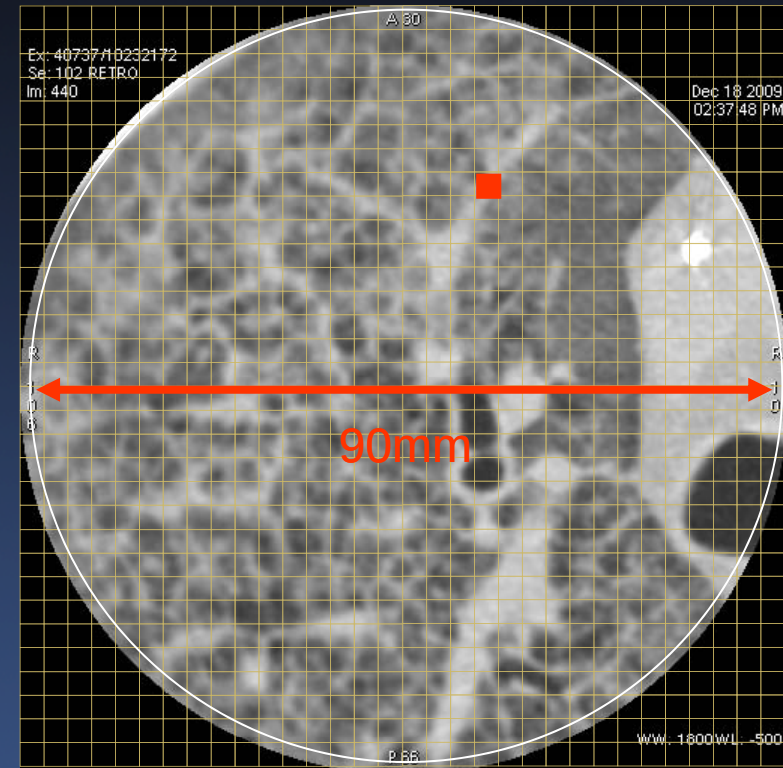


Matrice de reconstruction

Matrice 512x512
DFOV 50cm $\rightarrow$ pixel = 1mm

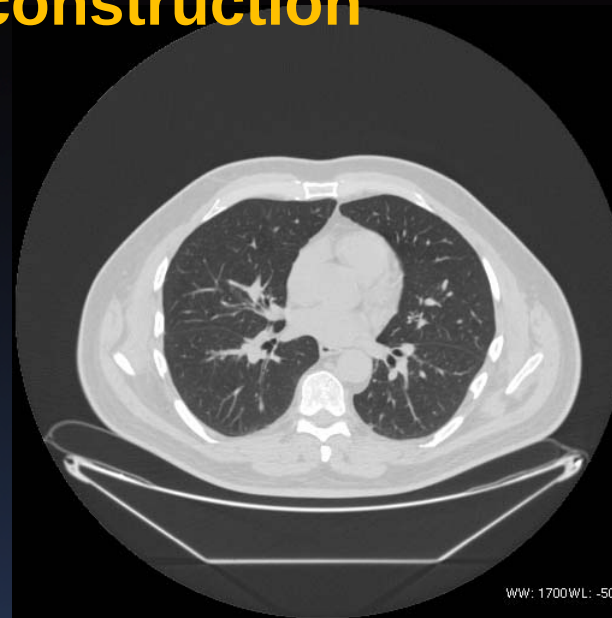


Matrice 512x512
DFOV 9cm $\rightarrow$ pixel = 0,2mm



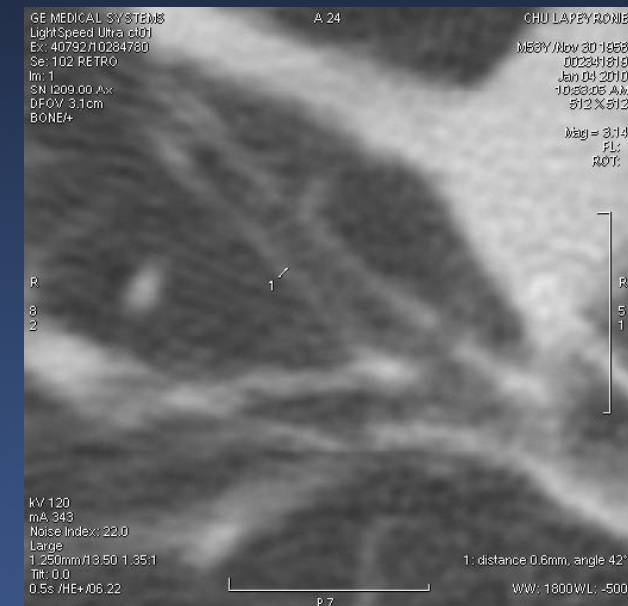
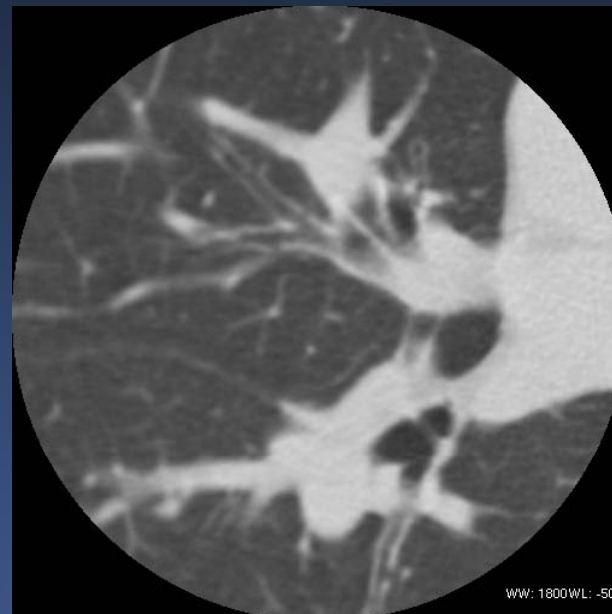
Matrice de reconstruction

DFOV de 50 cm
Images composées
de pixels de 1 mm

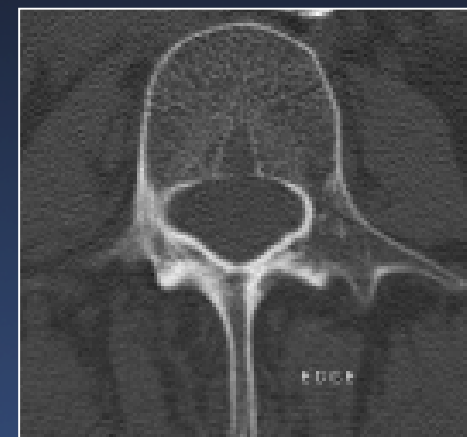
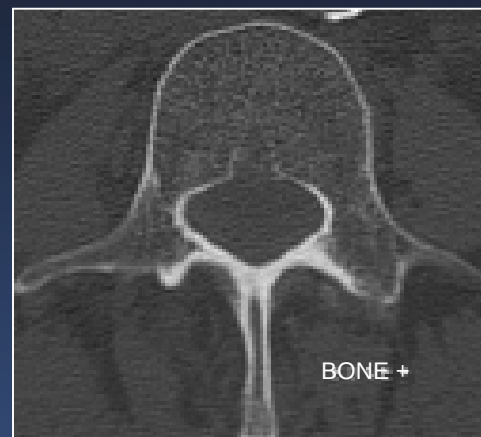
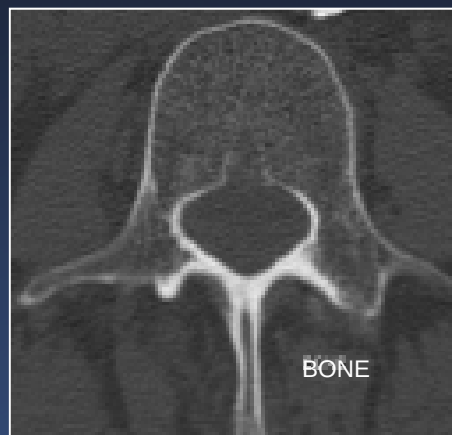
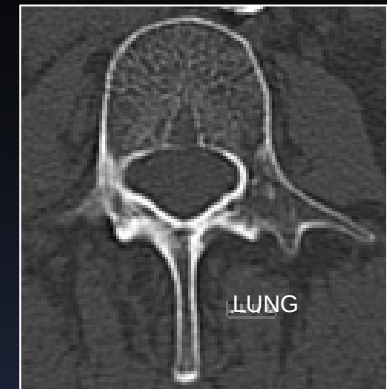
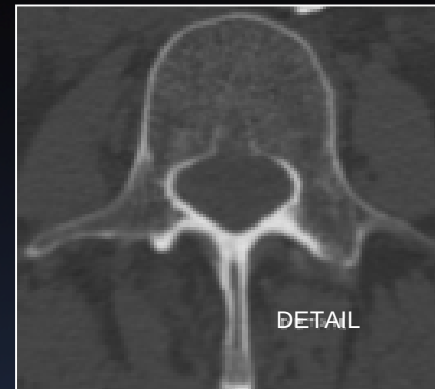
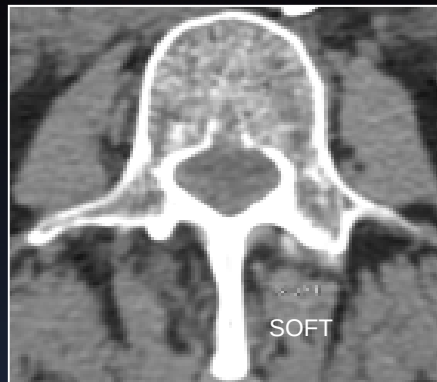


Mêmes données
mais DFOV
différents

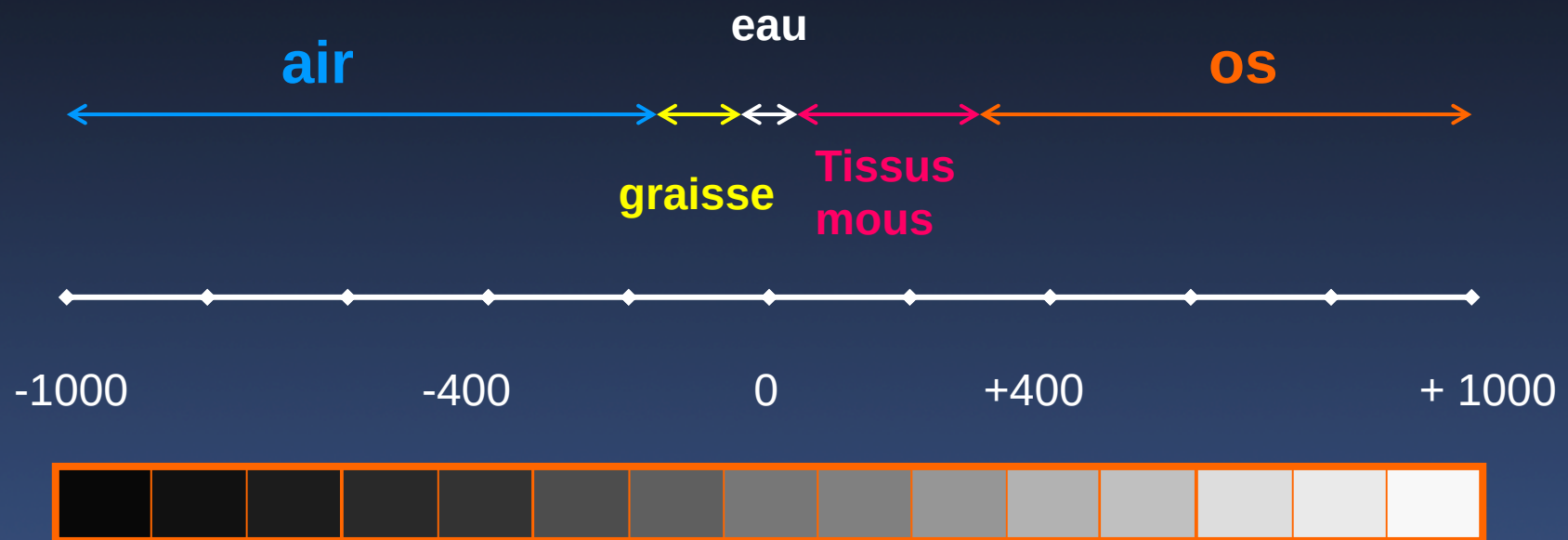
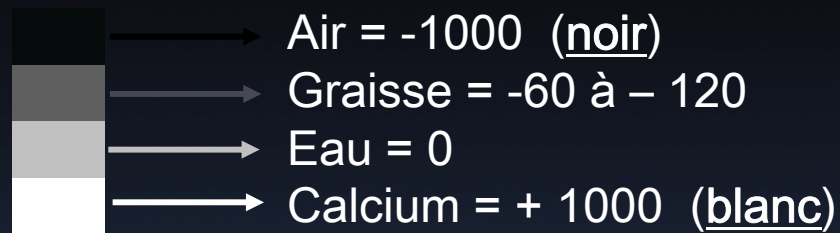
DFOV de 9.6 cm
Images composées
de pixels de 0.2 mm



Filtres de reconstruction



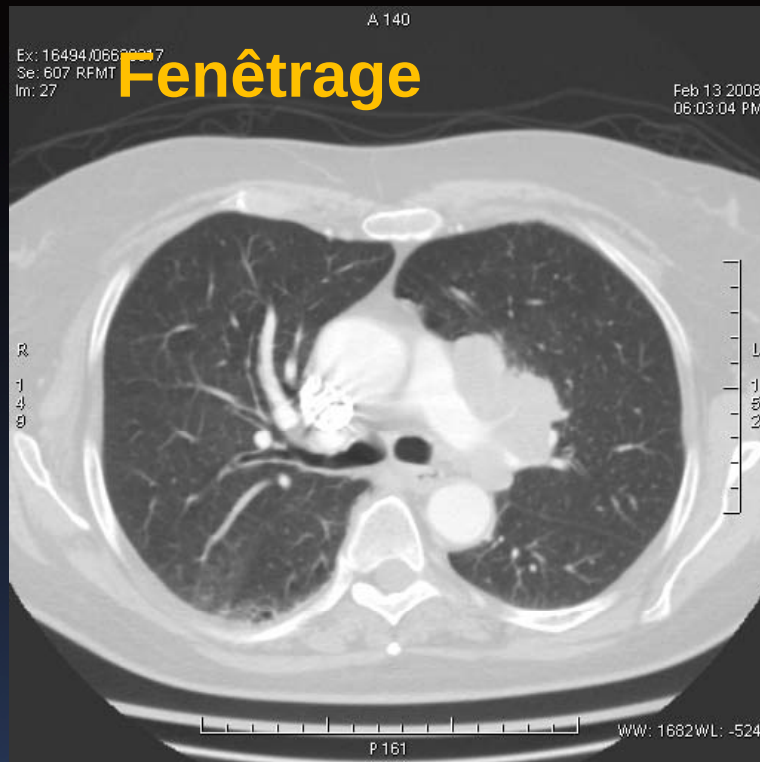
Echelle d'Hounsfield



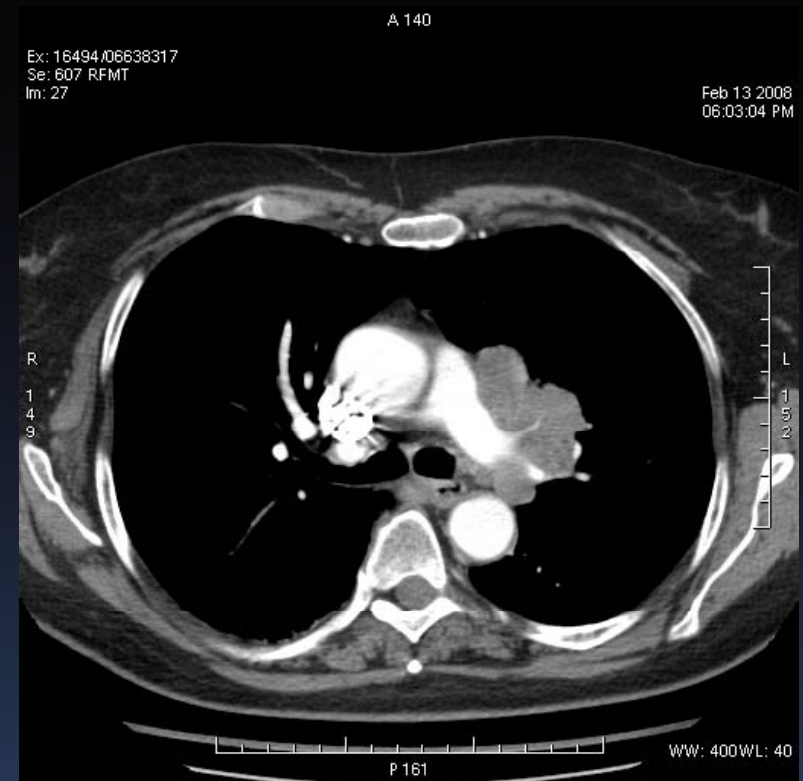
Fenêtrage

- WL (window level - centre - niveau) :
valeur UH de la densité moyenne à visualiser.
- WW (window width - fenêtre) :
détermine le nombre d'unités Hounsfield représentées par chaque niveau de gris.

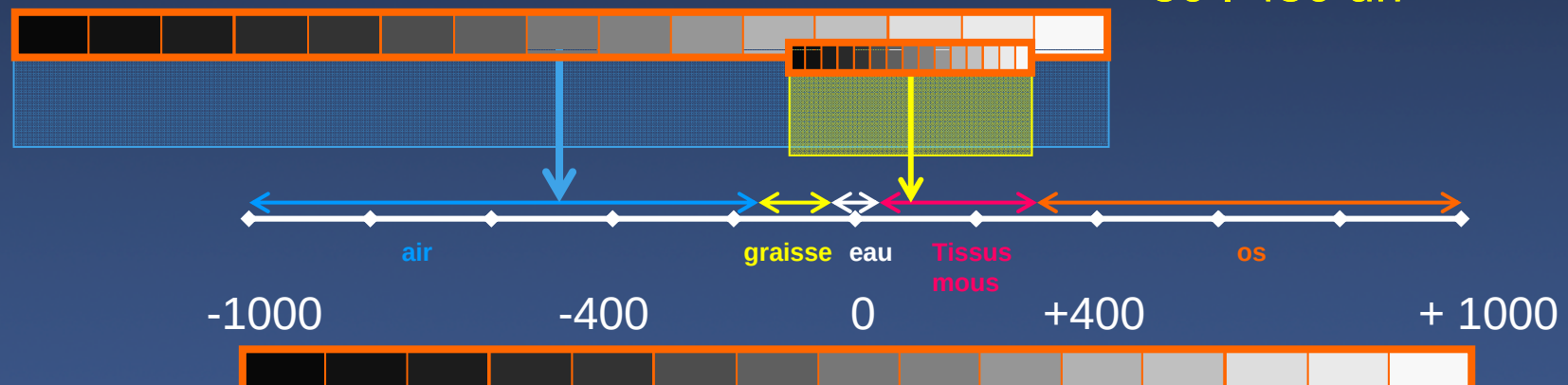
Cerveau	WW 135	WL 45
Abdomen	WW 400	WL 40
Médiastin	WW 350	WL 50
Poumon	WW 1700	WL -600
Os	WW 2500	WL 500
Rachis	WW 250	WL 35
Oreille Moyenne	WW 4000	WL 400



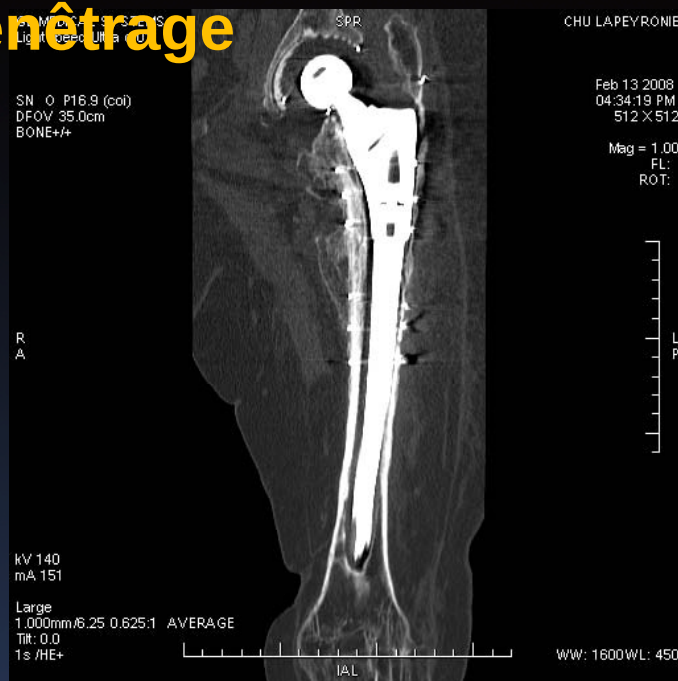
Fenêtrage parenchymateuse
-500 . 1800 uh



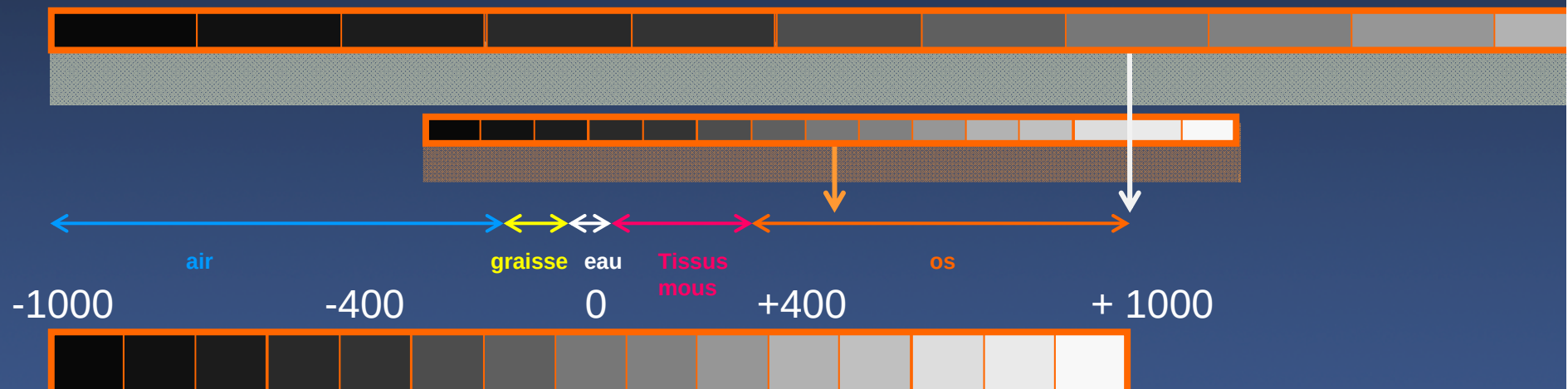
Fenêtrage médiastinale
50 . 450 uh



Fenêtrage

Fenêtre osseuse
450 . 1600 uh

Fenêtre osseuse étendue



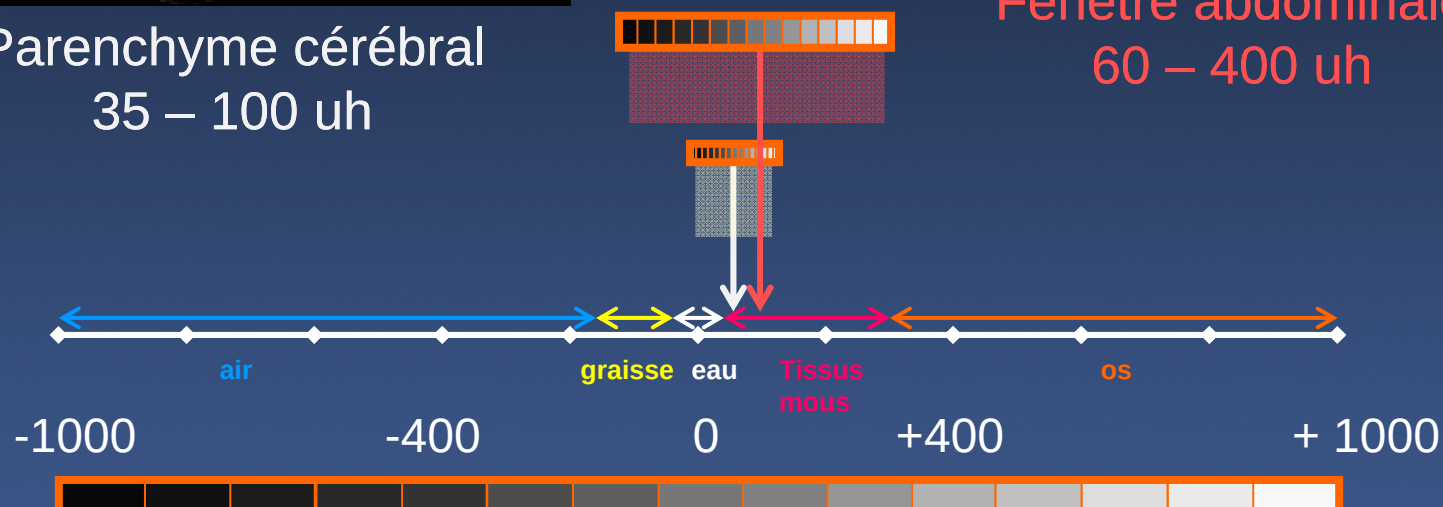
Fenêtrage



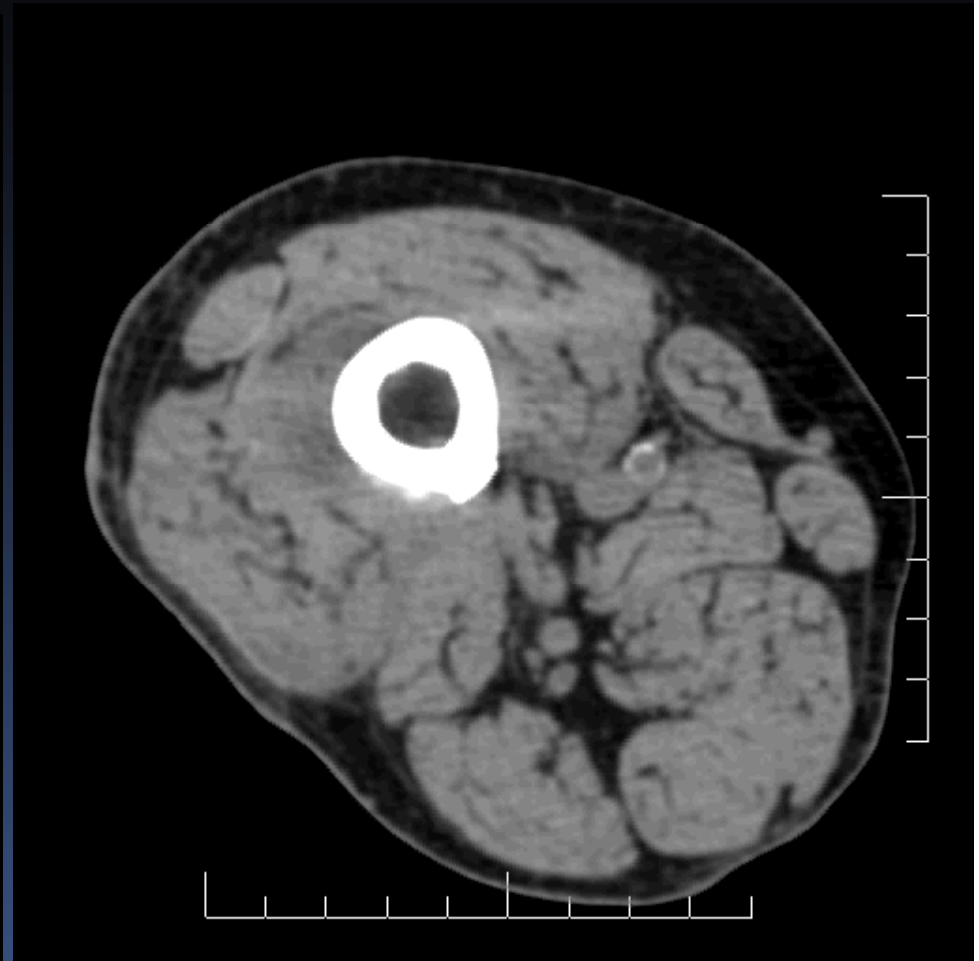
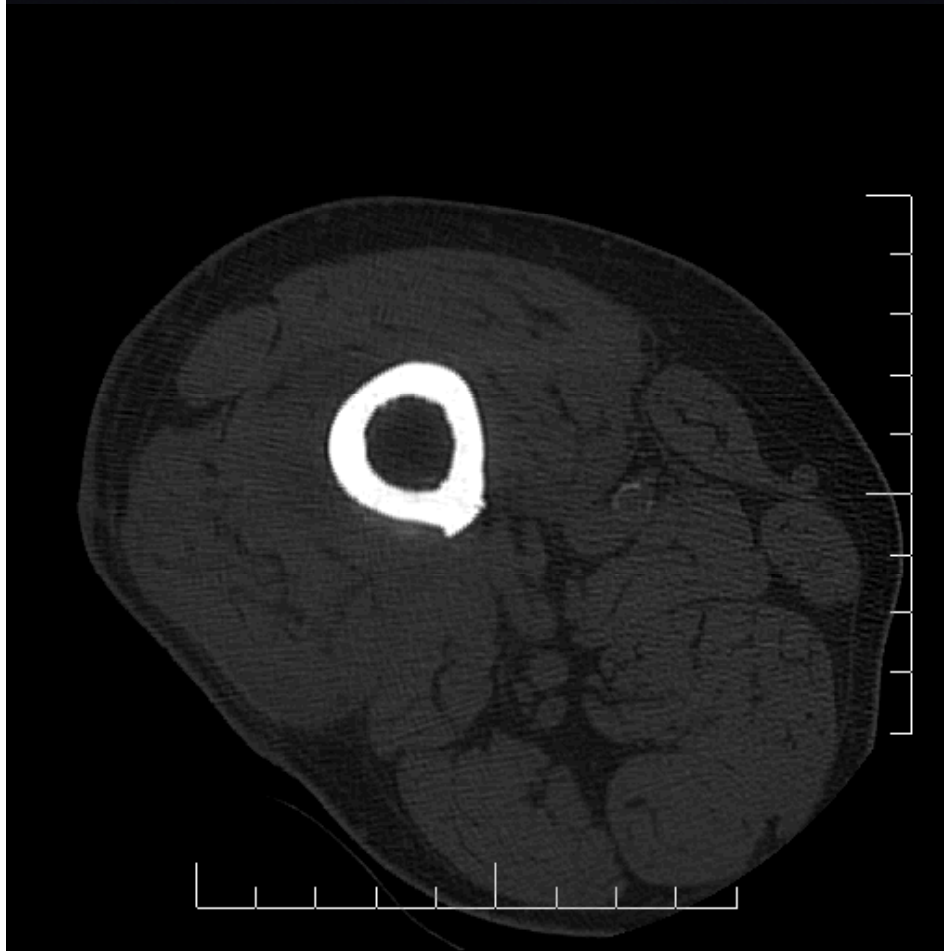
Parenchyme cérébral
35 – 100 uh



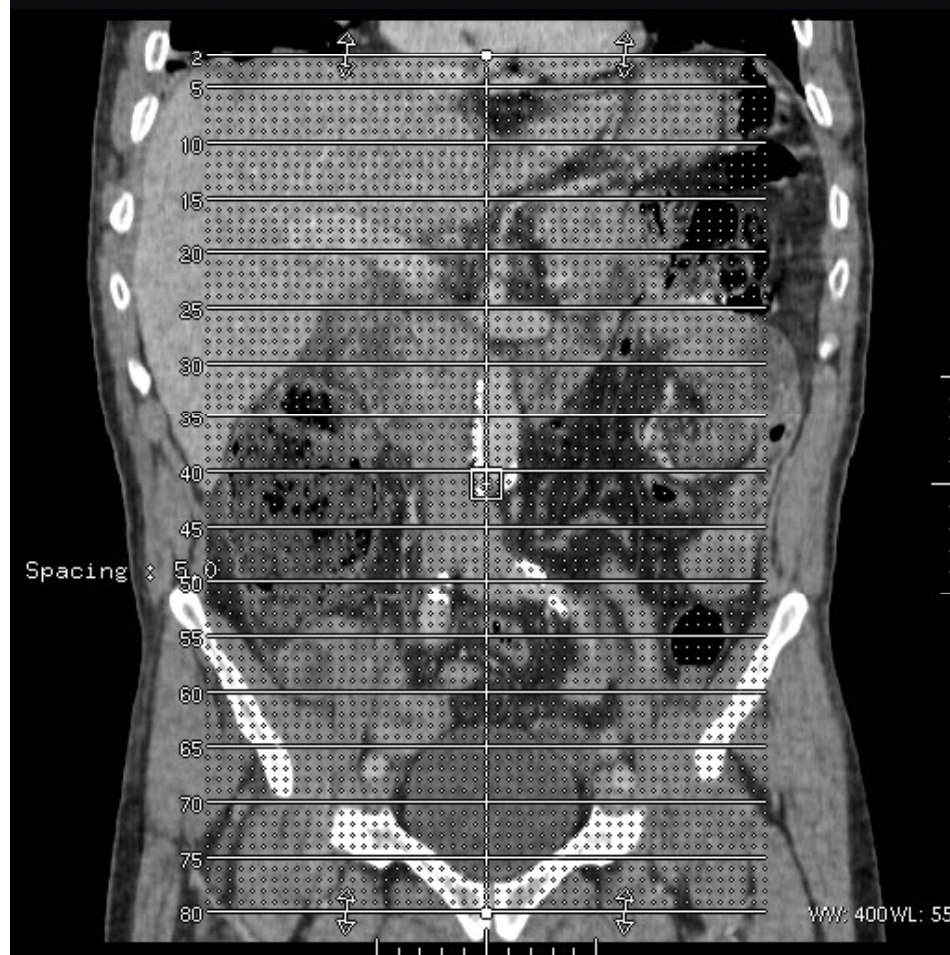
Fenêtrage abdominale
60 – 400 uh



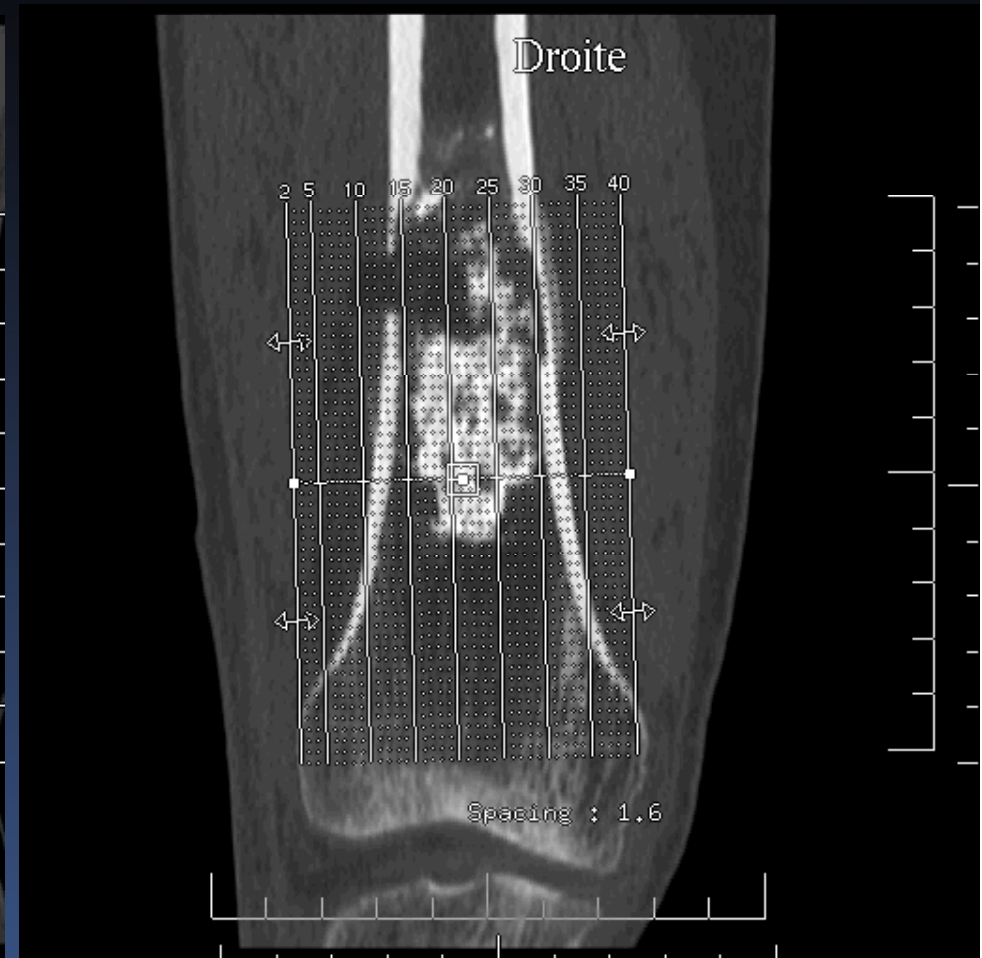
TDM



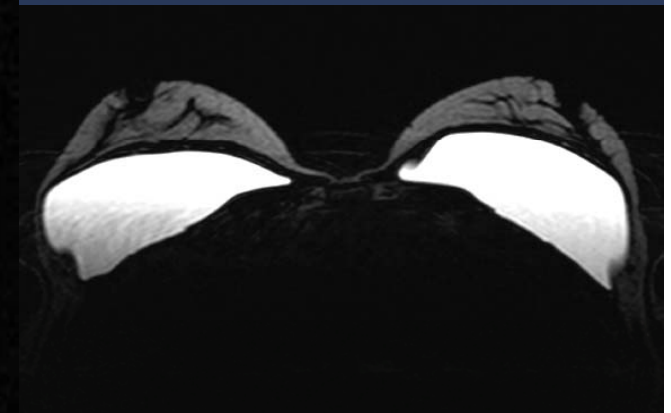
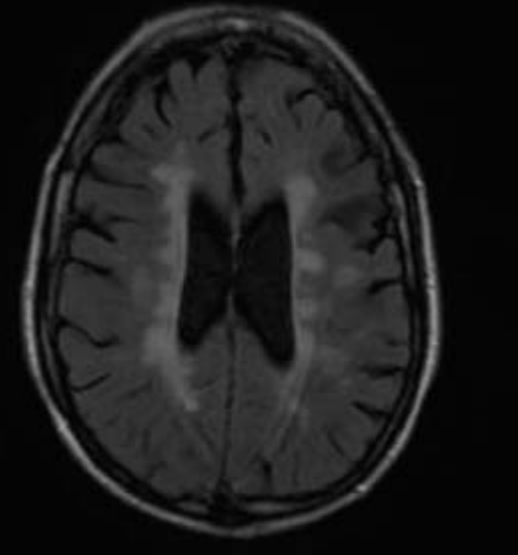
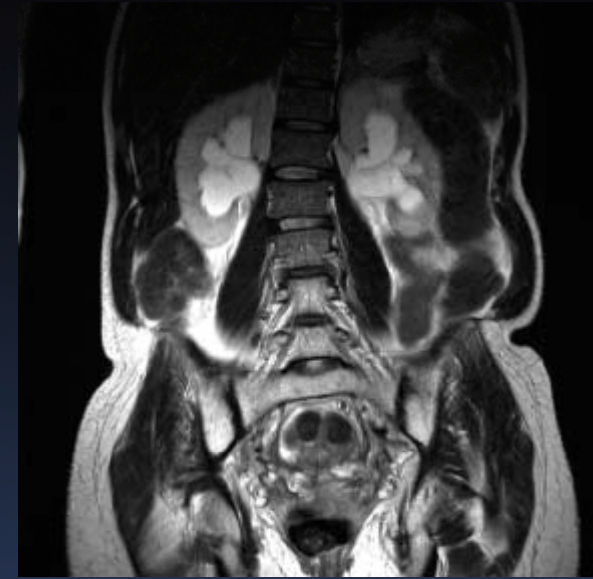
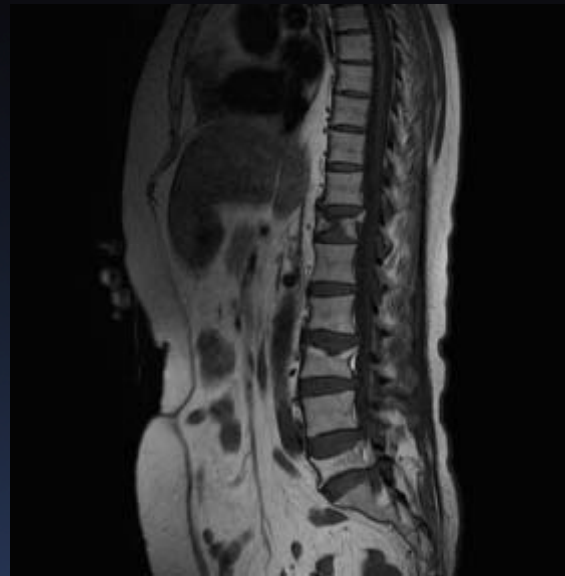
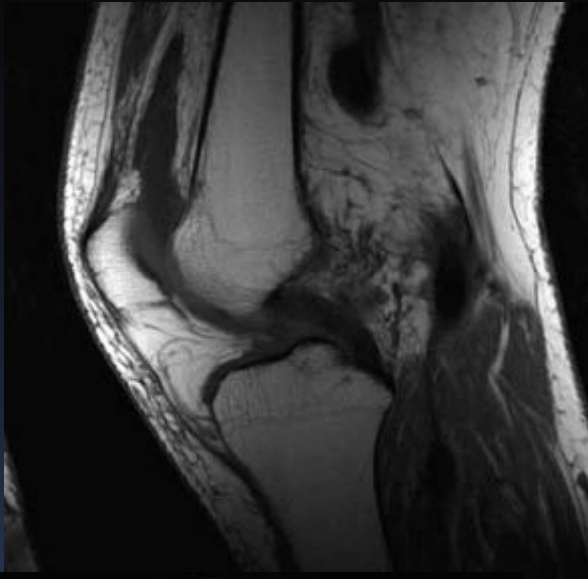
TDM



TDM



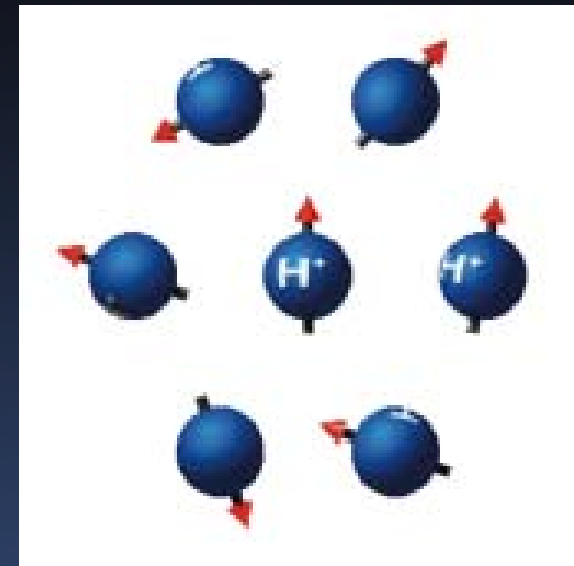
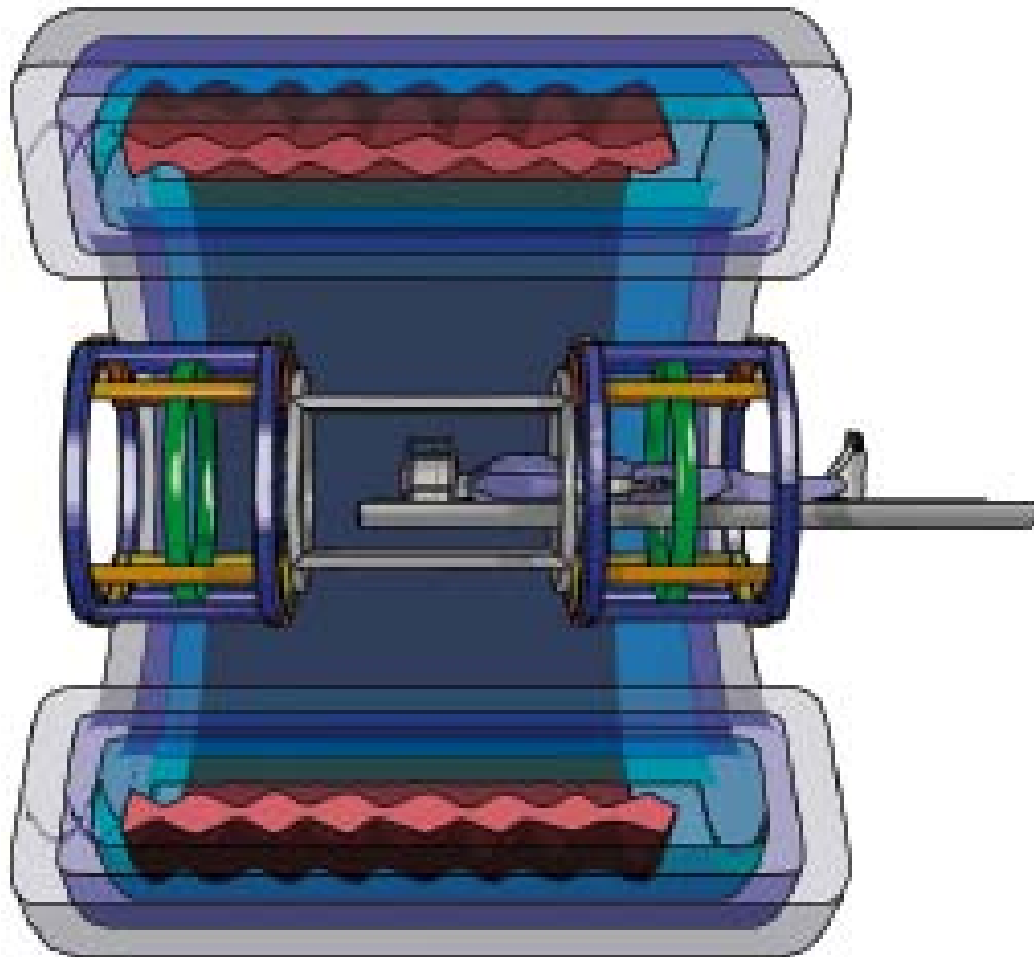
Imagerie par résonance magnétique : IRM



Imagerie par résonance magnétique : IRM



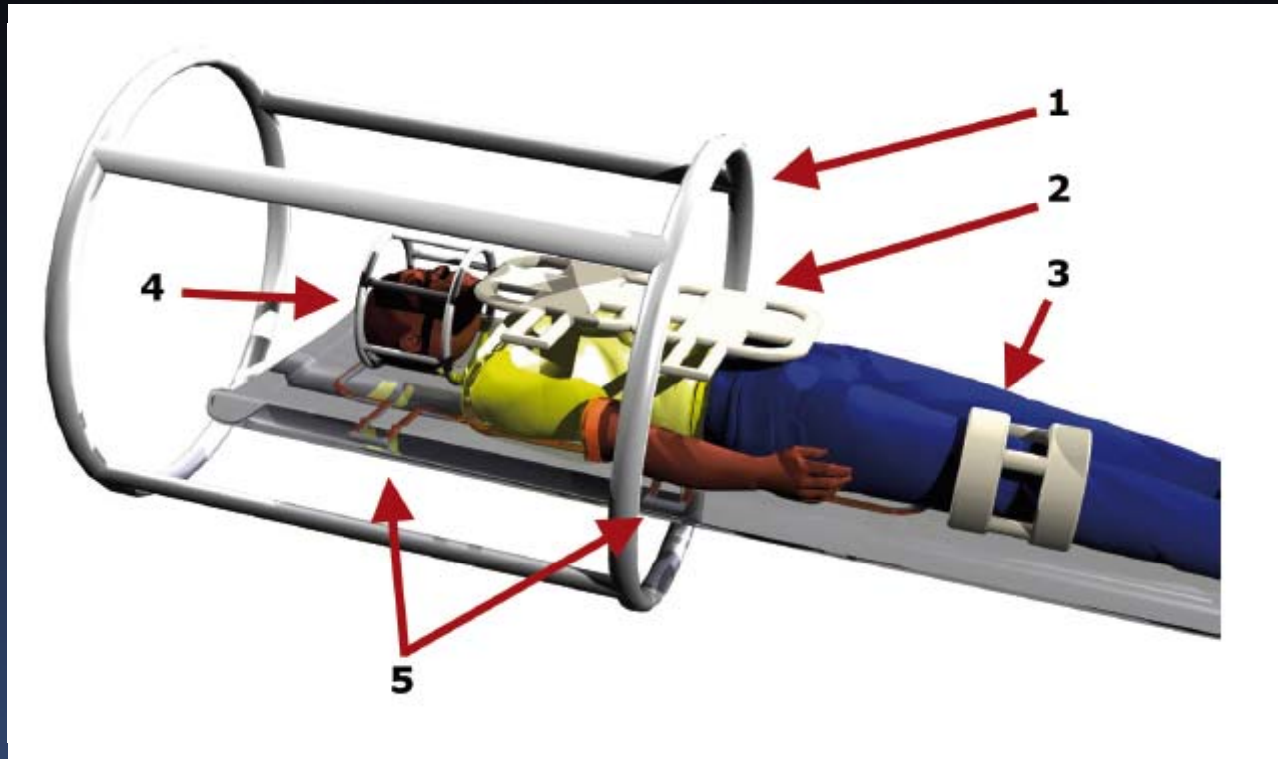
Imagerie par résonance magnétique : IRM



Imagerie par résonance magnétique : IRM



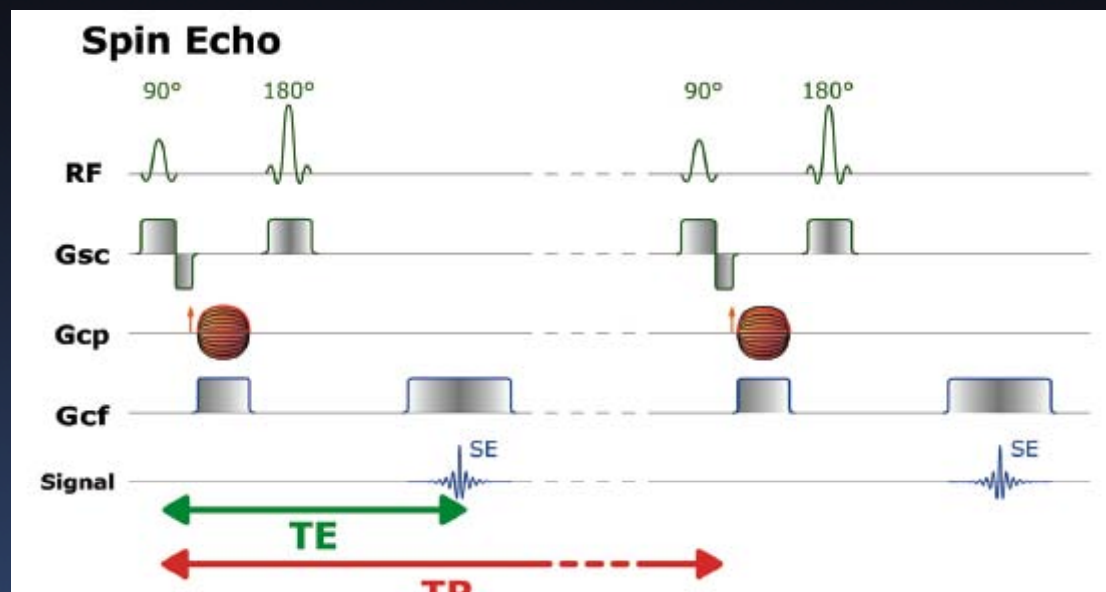
Imagerie par résonance magnétique : IRM



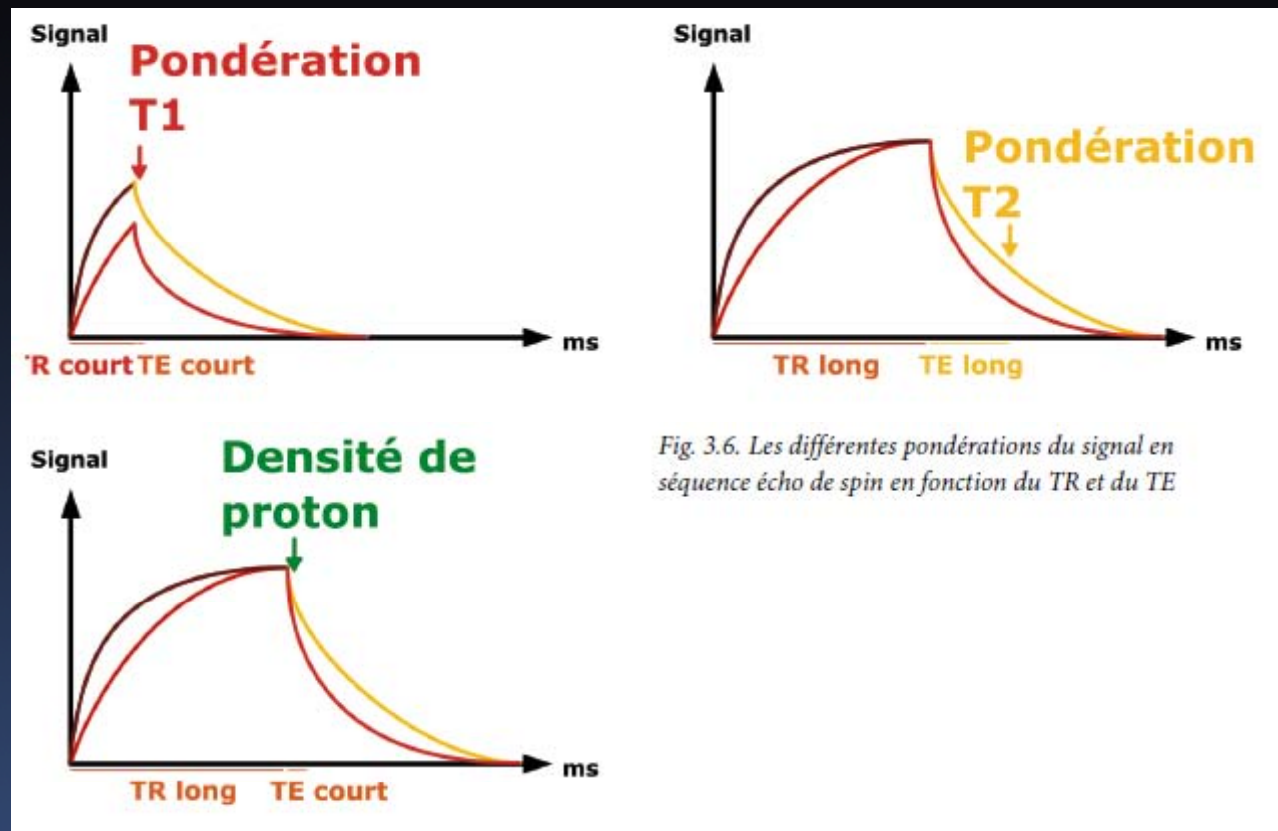
Imagerie par résonance magnétique : IRM



Imagerie par résonance magnétique : IRM



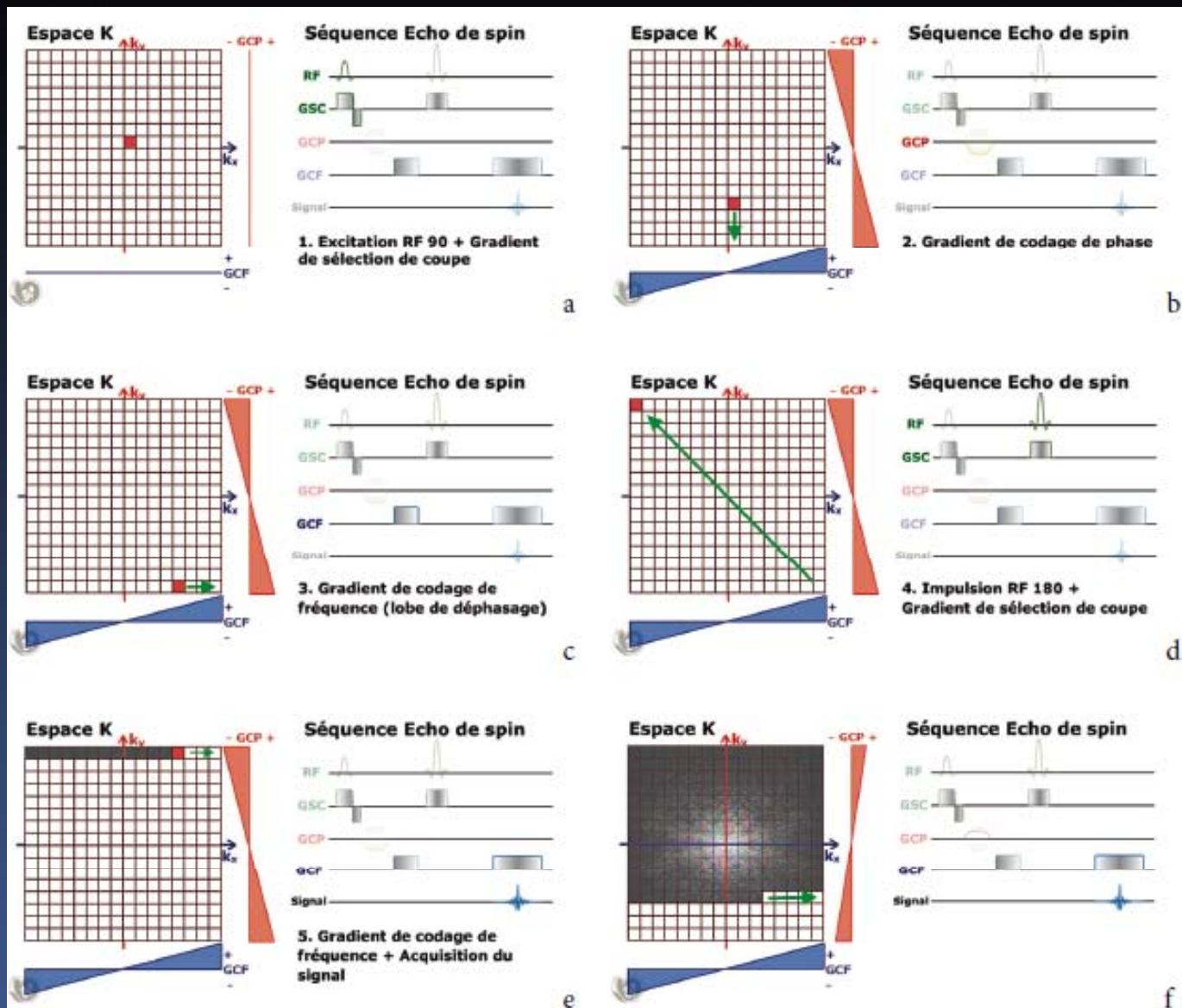
Imagerie par résonance magnétique : IRM



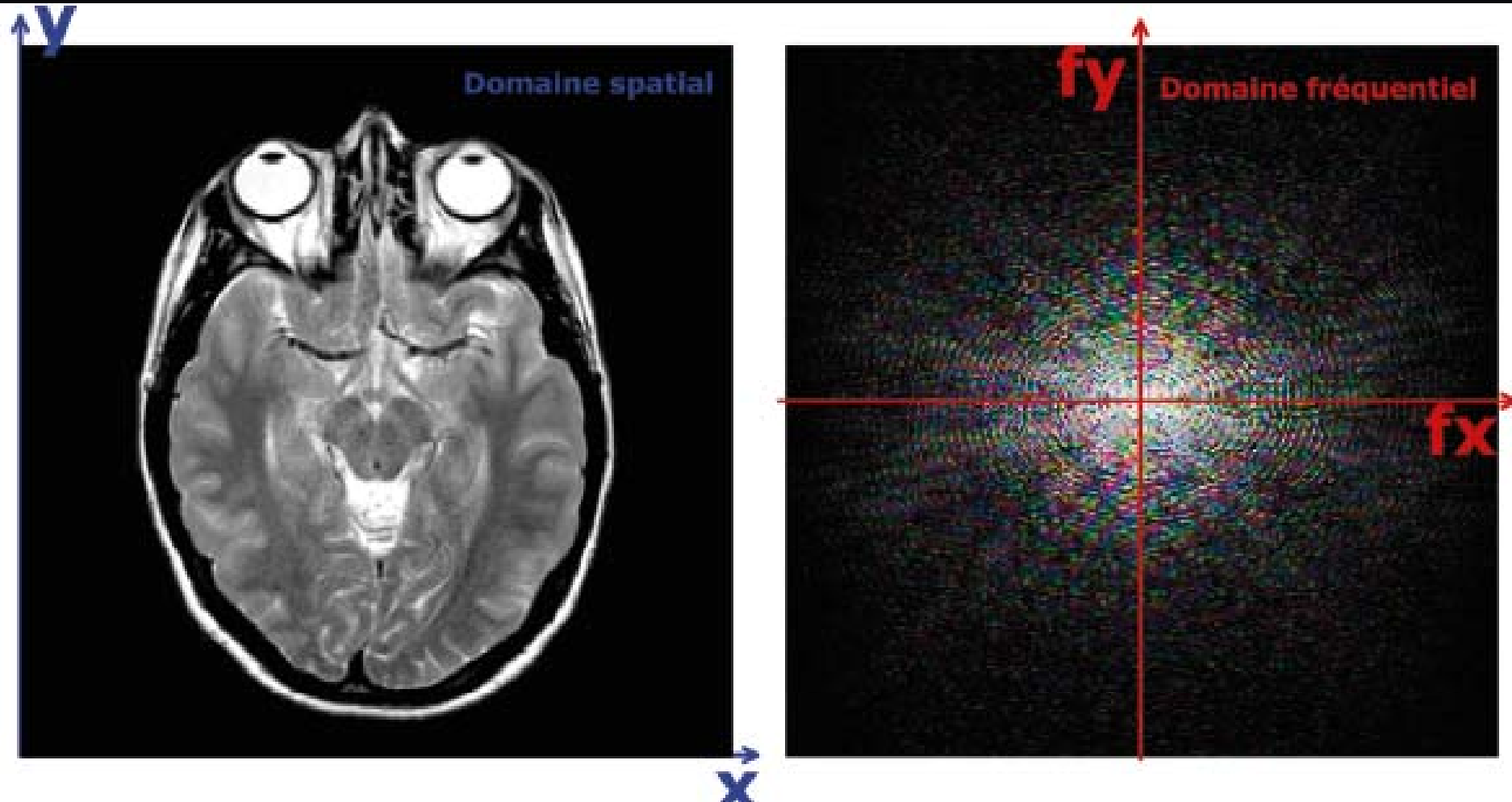
Imagerie par résonance magnétique : IRM



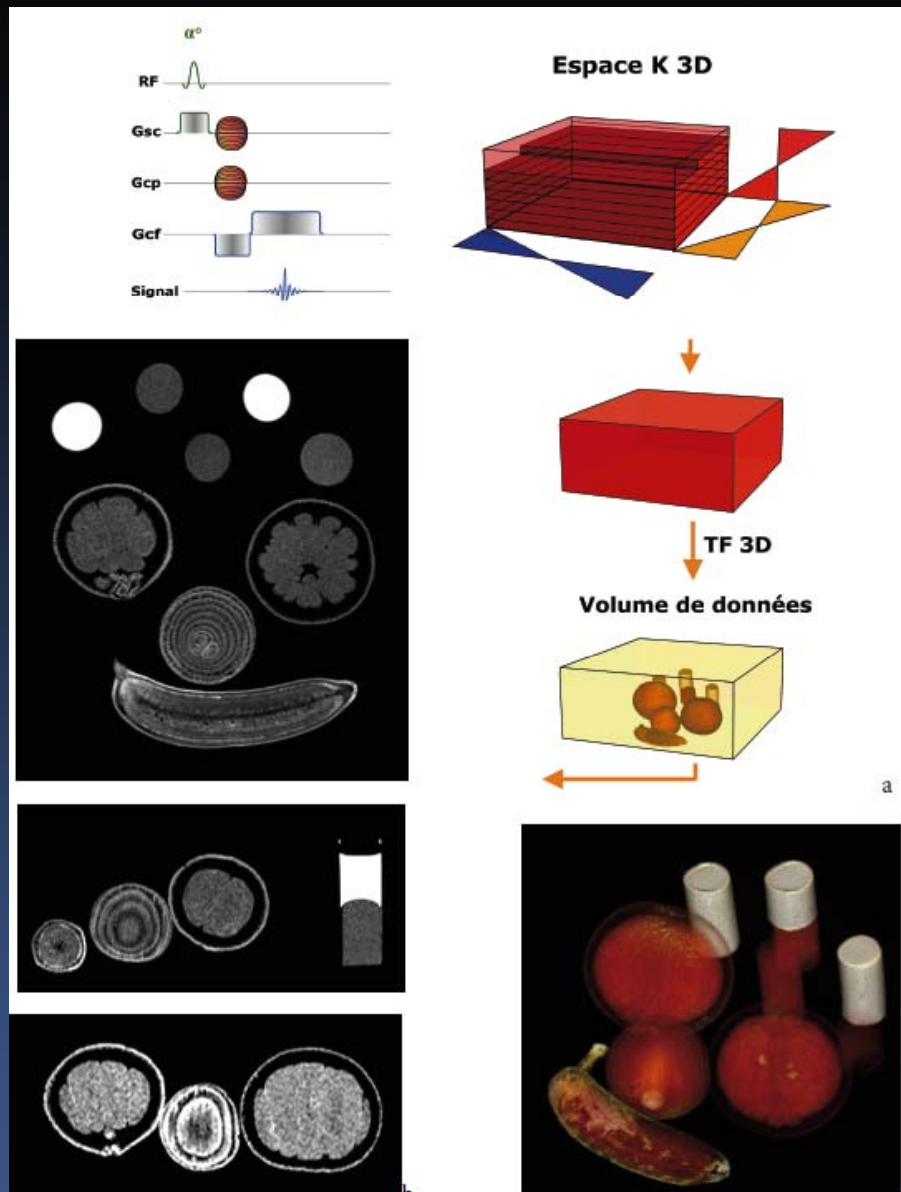
Imagerie par résonance magnétique : IRM



Imagerie par résonance magnétique : IRM



Imagerie par résonance magnétique : IRM



Format des images médicales

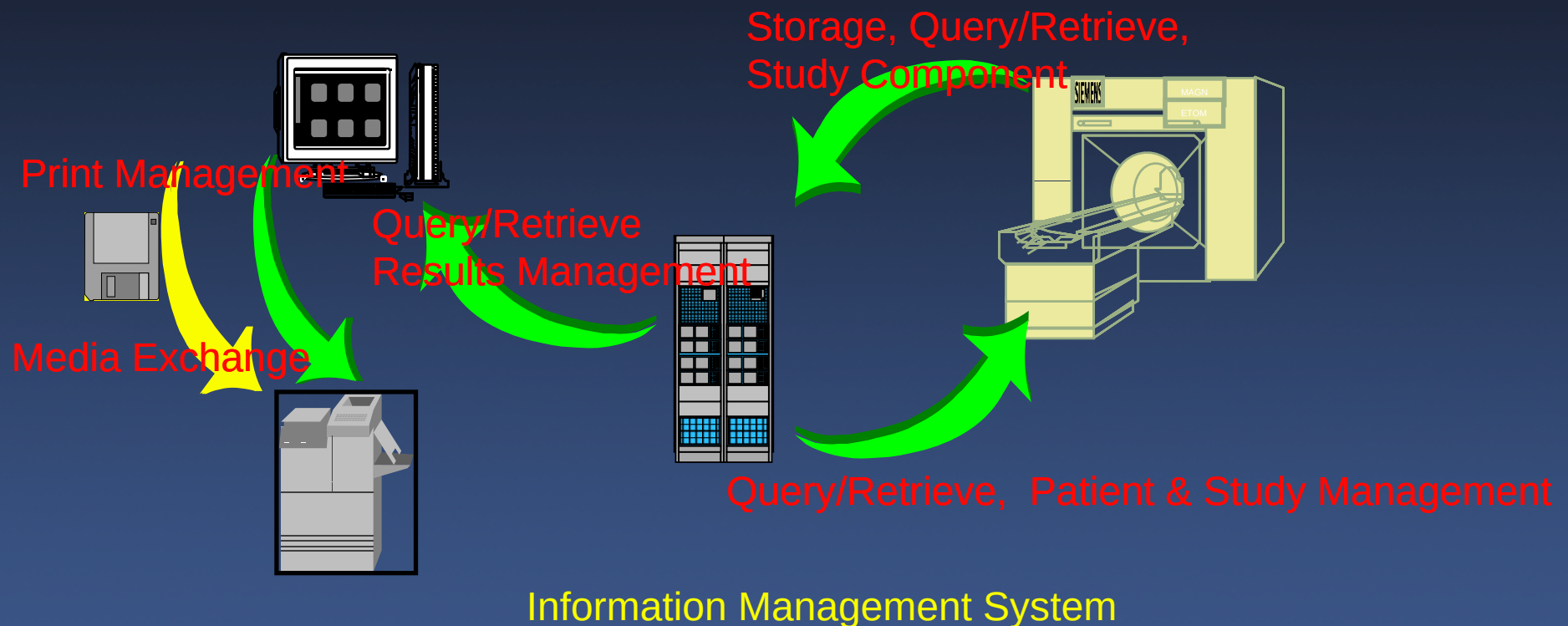
DICOM

Digital Imaging
Communications
in Medicine

DICOM

Créé par l'American College of Radiology et la NEMA (National Electric Manufacturers Association)

Faciliter les transferts d'images



DICOM

Numéro	Intitulé
1	Introduction and Overview
2	Conformance
3	Information Object Definitions
4	Service Class Specifications
5	Data Structures and Encoding
6	Data Dictionary
7	Message Exchange
8	Network Communication Support for Message Exchange
10	Media Storage and File Format for Data Interchange
11	Media Storage Application Profiles
12	Media Formats and Physical Media for Data Interchange
14	Grayscale Standard Display Function
15	Security Profiles
16	Content Mapping Resource
17	Explanatory Information
18	Web Access to DICOM Persistent Objects (WADO)

DICOM

- ⦿ Protocole d'échange
- ⦿ Format
 - Champs de données
 - Champ image

<http://medical.nema.org/>

Module Image : Imagerie médicale

EVALUATION DES PROCEDURES DIAGNOSTIQUES

Dr Denis Hoa



IMAIOS SAS
Montpellier - France



CHU Lapeyronie



LIRMM

Evaluation des procédures diagnostiques

- Biostatistiques et valeurs diagnostiques
- Courbes ROC

Evaluation diagnostique d'un test

1. **Reproductibilité du test**
 - Intra et inter observateur
2. **+/- Détermination d'un seuil**
 - Pour les tests qui rendent une valeur quantitative
3. **Valeur diagnostique**
 - Sensibilité, Spécifité, VPP, VPN, Exactitude
4. **Comparaison de tests**

Evaluation diagnostique d'un test

	Test qualitatif	Test quantitatif
Reproductibilité ⇒ Etude de concordance	Plusieurs lectures du même examen par le même observateur et par d'autres observateurs	
	Coefficient kappa simple ou pondéré	Coefficient de corrélacion intra classe
Seuil		Courbe ROC
Valeurs diagnostiques	Calculs de pourcentages + intervalle de confiance	
Comparaison de différents tests diagnostiques	Comparaison de pourcentages	Comparaison d'aires sous les courbes ROC

Valeurs diagnostiques

Table de Ring_sign_L2 par Fonctionnel				
Ring_sign_L2	Fonctionnel			
FREQUENCE Pct en ligne Pct en col.		No	Yes	Total
.	122 100.00 77.22	0 0.00 0.00	0 0.00 0.00	122
No	29 38.67 18.35	42 56.00 93.33	4 5.33 10.81	75
Yes	7 16.28 4.43	3 6.98 6.67	33 76.74 89.19	43
Total	158	45	37	240

		True class			
		p	n		
Hypothesized class	Y	True Positives	False Positives	fp rate = $\frac{FP}{N}$	tp rate = $\frac{TP}{P}$
	N	False Negatives	True Negatives	precision = $\frac{TP}{TP+FP}$	recall = $\frac{TP}{P}$
Column totals:		P	N	accuracy = $\frac{TP+TN}{P+N}$	
				F-measure = $\frac{2}{1/\text{precision}+1/\text{recall}}$	

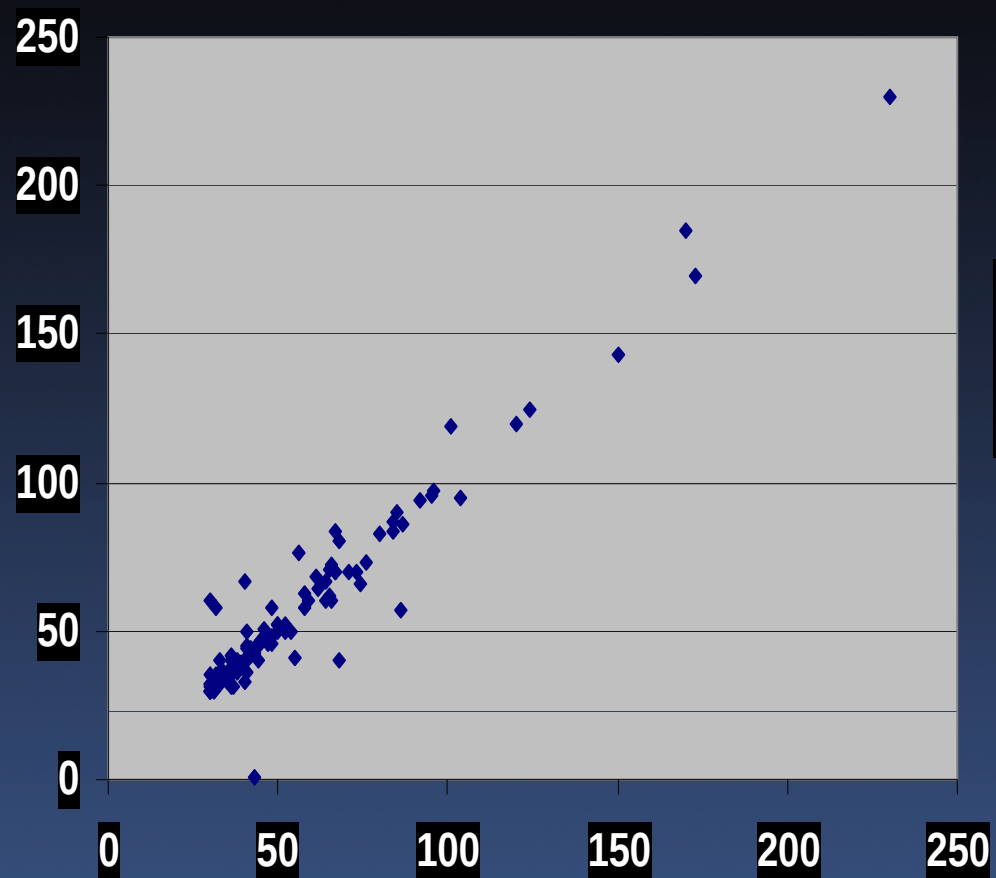
Test=Ring_sign_L2 Ref=Fonctionnel	rate	Normal Approx. 95% CI	Poisson Approx. 95% CI	Exact Binomial 95% CI	Score Binomial 95% CI
Sensitivity	89.2%	(79.2% - 99.2%)	(61.4% - 125.3%)	(74.6% - 97.0%)	(75.3% - 95.7%)
Specificity	93.3%	(86.0% - 100.6%)	(67.3% - 126.2%)	(81.7% - 98.6%)	(82.1% - 97.7%)
PPV	91.7%	(82.6% - 100.7%)	(63.1% - 128.7%)	(77.5% - 98.2%)	(78.2% - 97.1%)
PNV	91.3%	(83.2% - 99.4%)	(65.8% - 123.4%)	(79.2% - 97.6%)	(79.7% - 96.6%)
ACCURACY	91.5%	(85.4% - 97.5%)	(71.9% - 114.7%)	(83.2% - 96.5%)	(83.4% - 95.8%)

Etude de concordance

Table de Ring_sign par Ring_sign_L2			
Ring_sign_L1	Ring_sign_L2		
FREQUENCE Pourcentage Pct en ligne Pct en col.	Non	Oui	
Non	69 58.97 92.00 93.24	6 5.13 8.00 13.95	75 64.10
Oui	5 4.27 11.90 6.76	37 31.62 88.10 86.05	42 35.90
Total	74 63.25	43 36.75	117 100.0
Fréquence manquante = 123			

Coefficient simple de Kappa	
Kappa	0.7968
ASE	0.0582
95% Limite de conf inf.	0.6827
95% Limite de conf sup.	0.9109

Etude de concordance

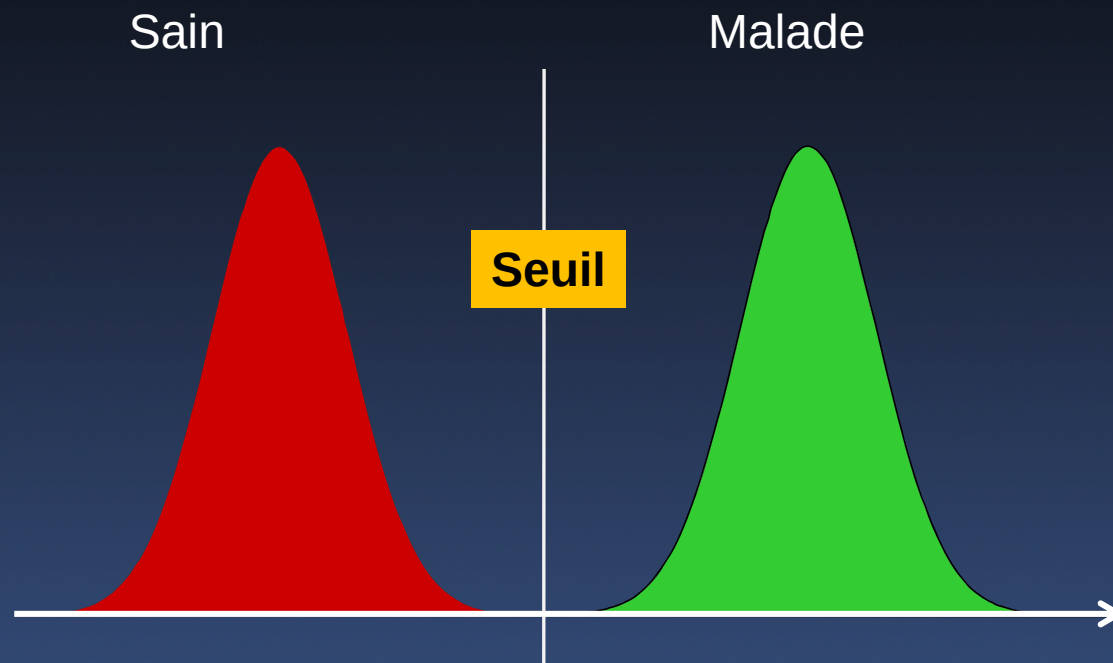


cic	cicinf	cicsup
0.96548	0.95066	0.97590

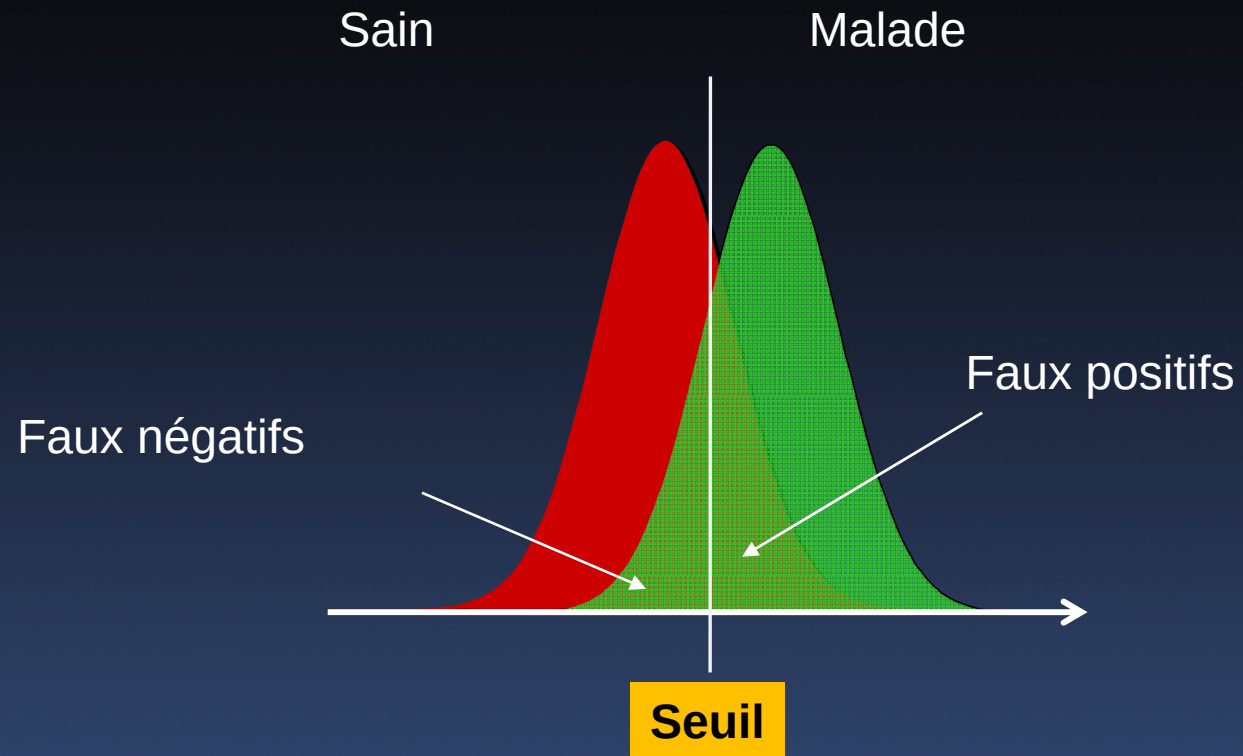
Objectifs (caricaturaux !)

- ⦿ Coefficient kappa
- ⦿ Coefficient de concordance intra-classe
- ⦿ Aire sous la courbe ROC
- ⦿ Sensibilité, Spécificité
- ⦿ VPP, VPN
- ⦿ Exactitude
- ⦿ Varient entre 0 et 1
 - Bon si $> 0,7$
 - Très bon si $> 0,8$
- Objectifs variables

Recherche de seuil : les courbes ROC



Recherche de seuil : les courbes ROC

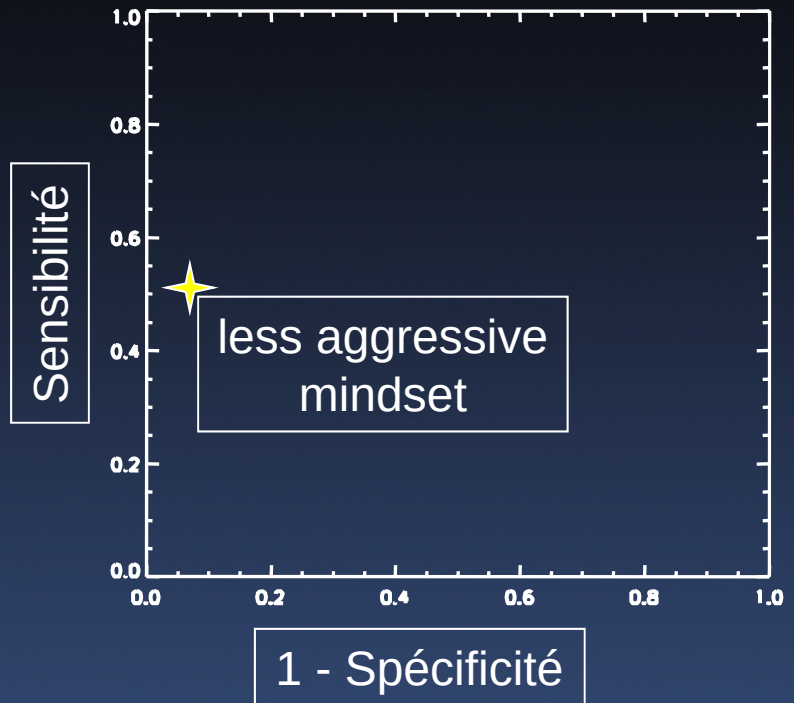


Non-diseased
patient

$\pi > 0.7$ is positive test

Seuil

Diseased
patient

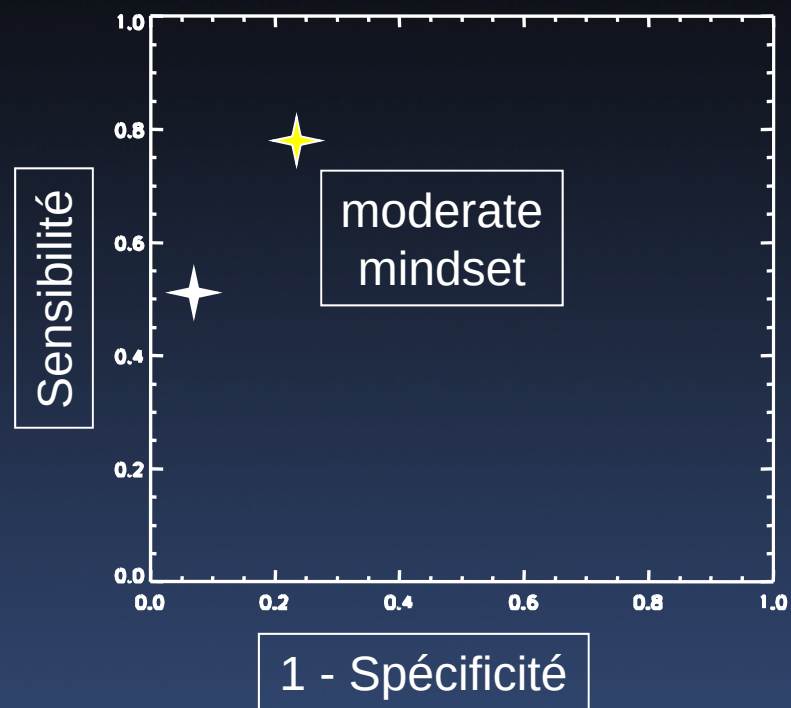
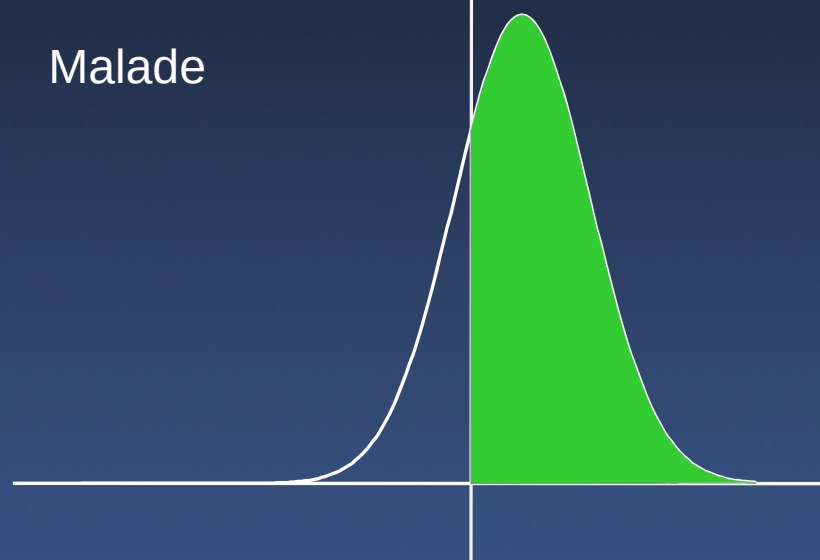


Sain

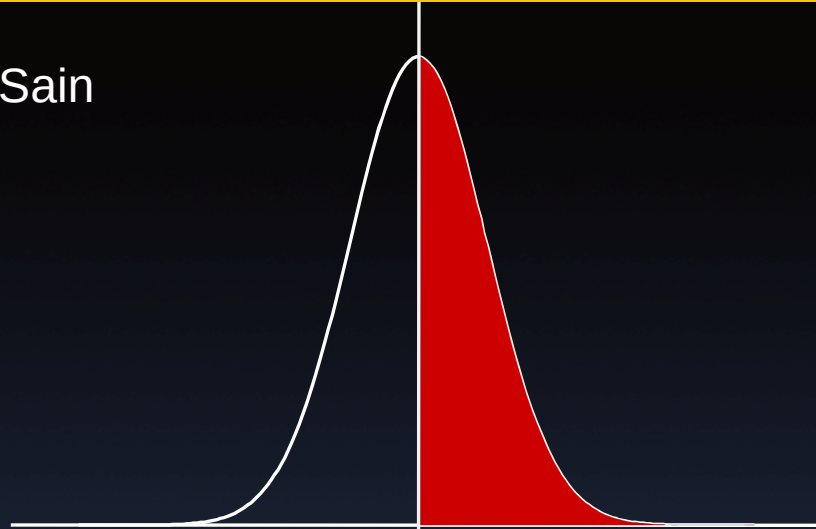


Seuil

Malade

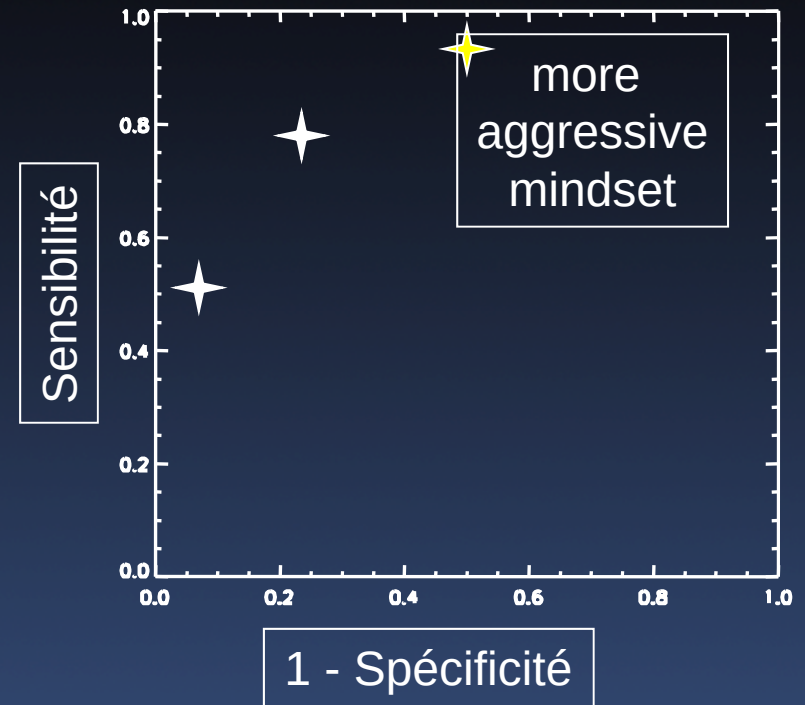
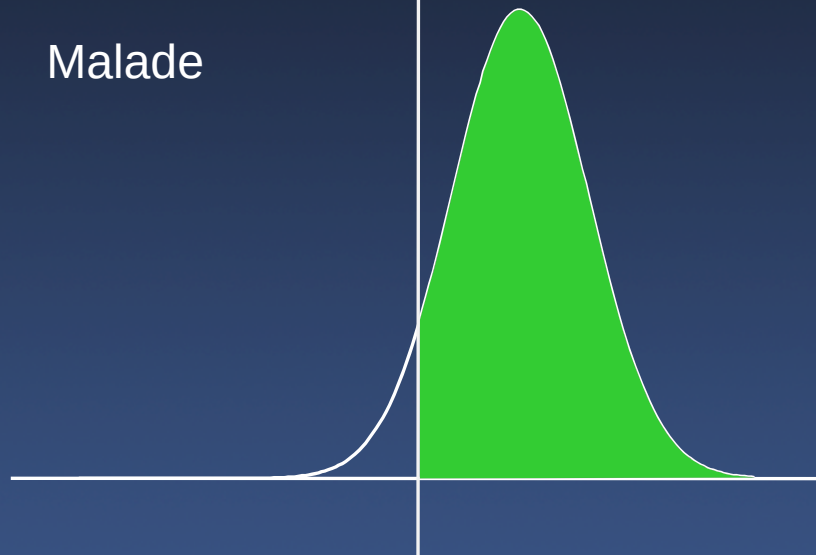


Sain



Seuil

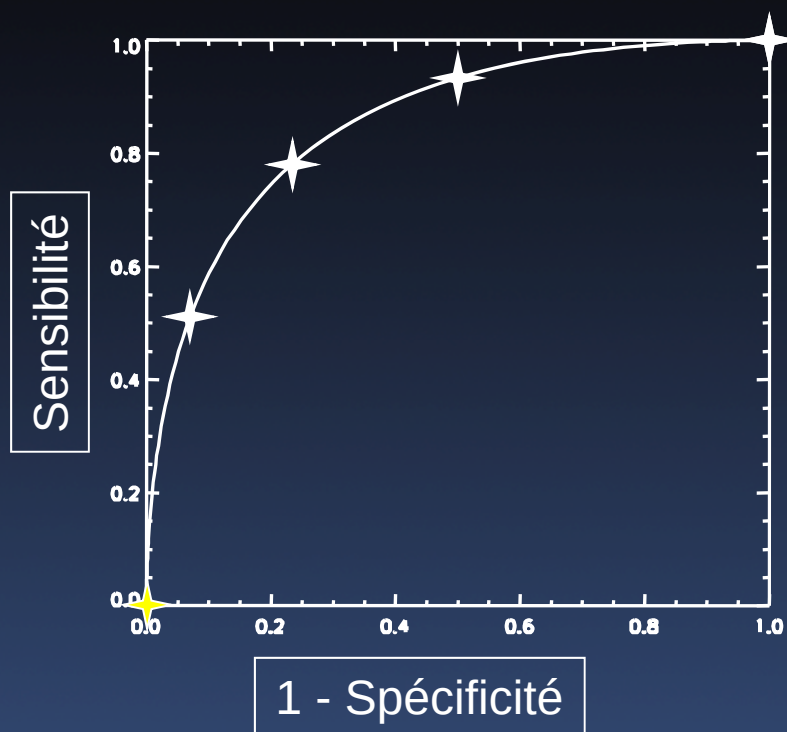
Malade

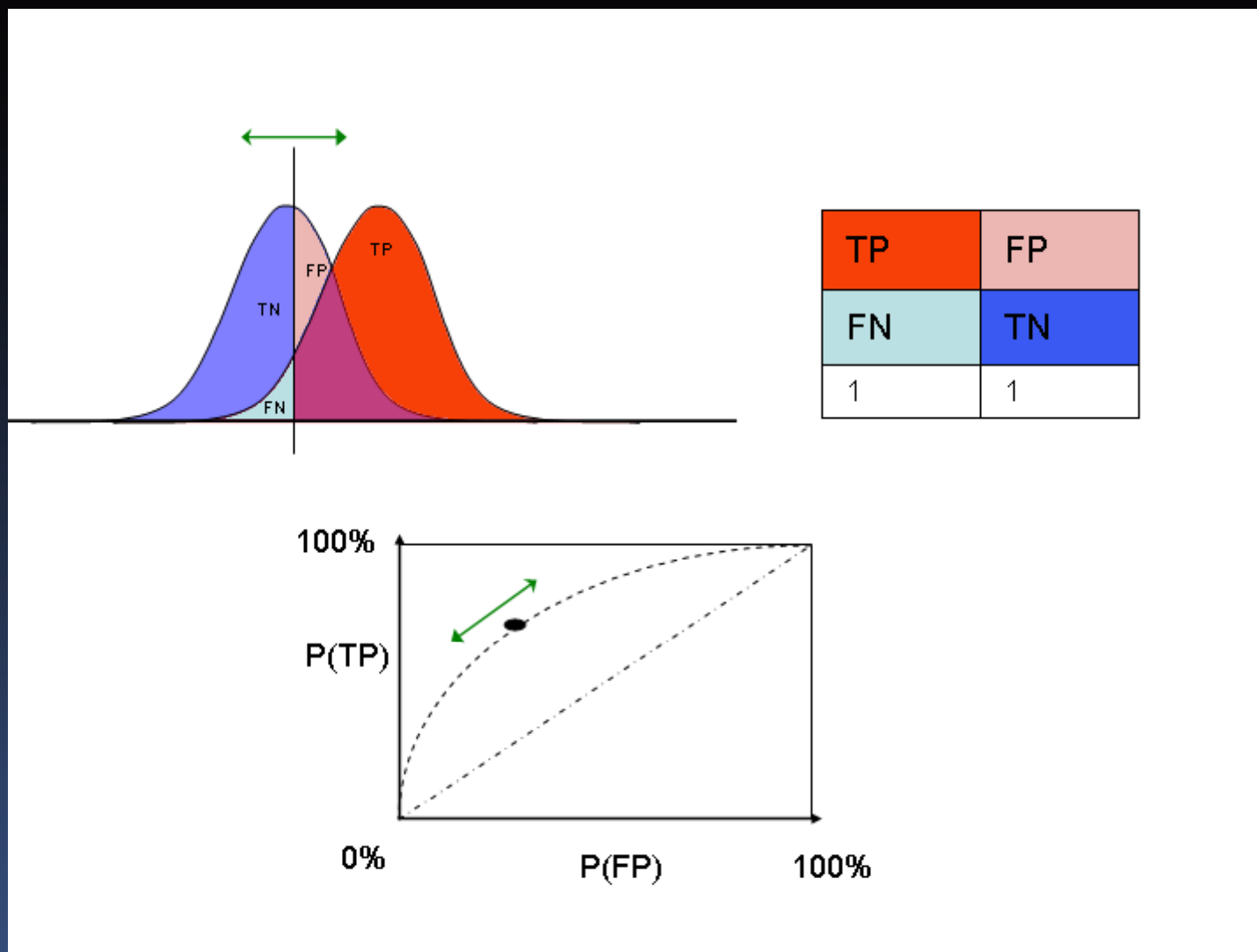


Sain

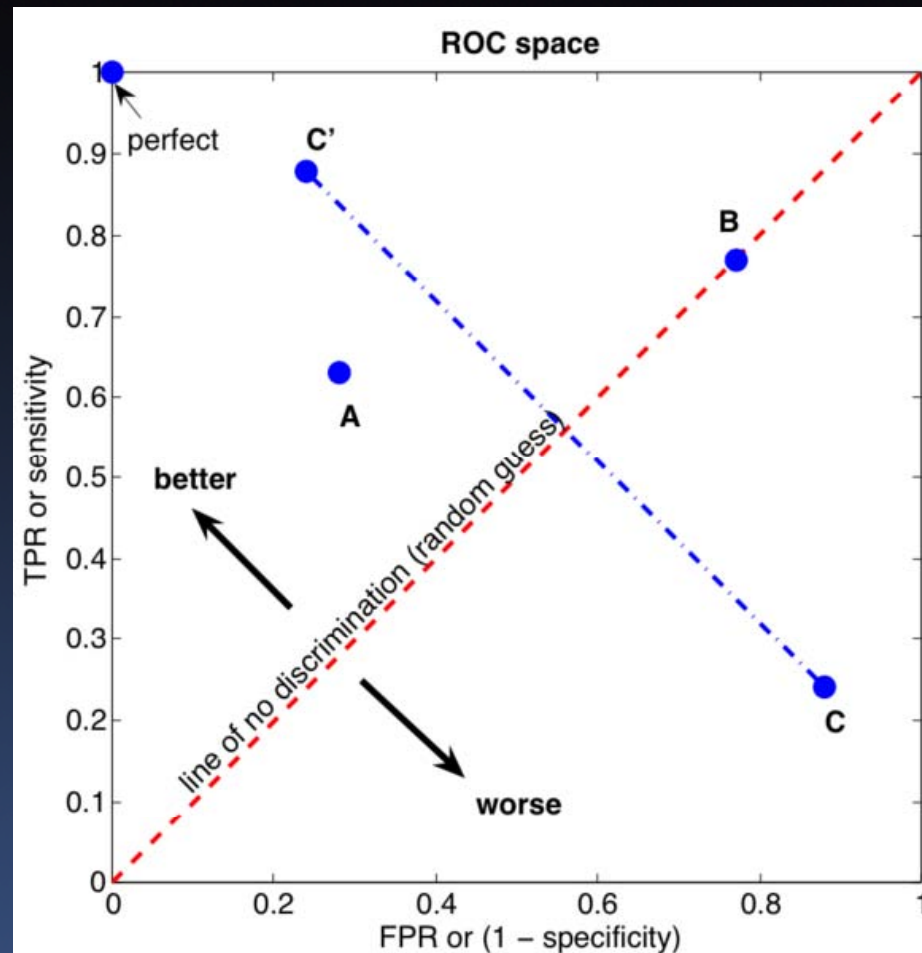
Seuil

Malade

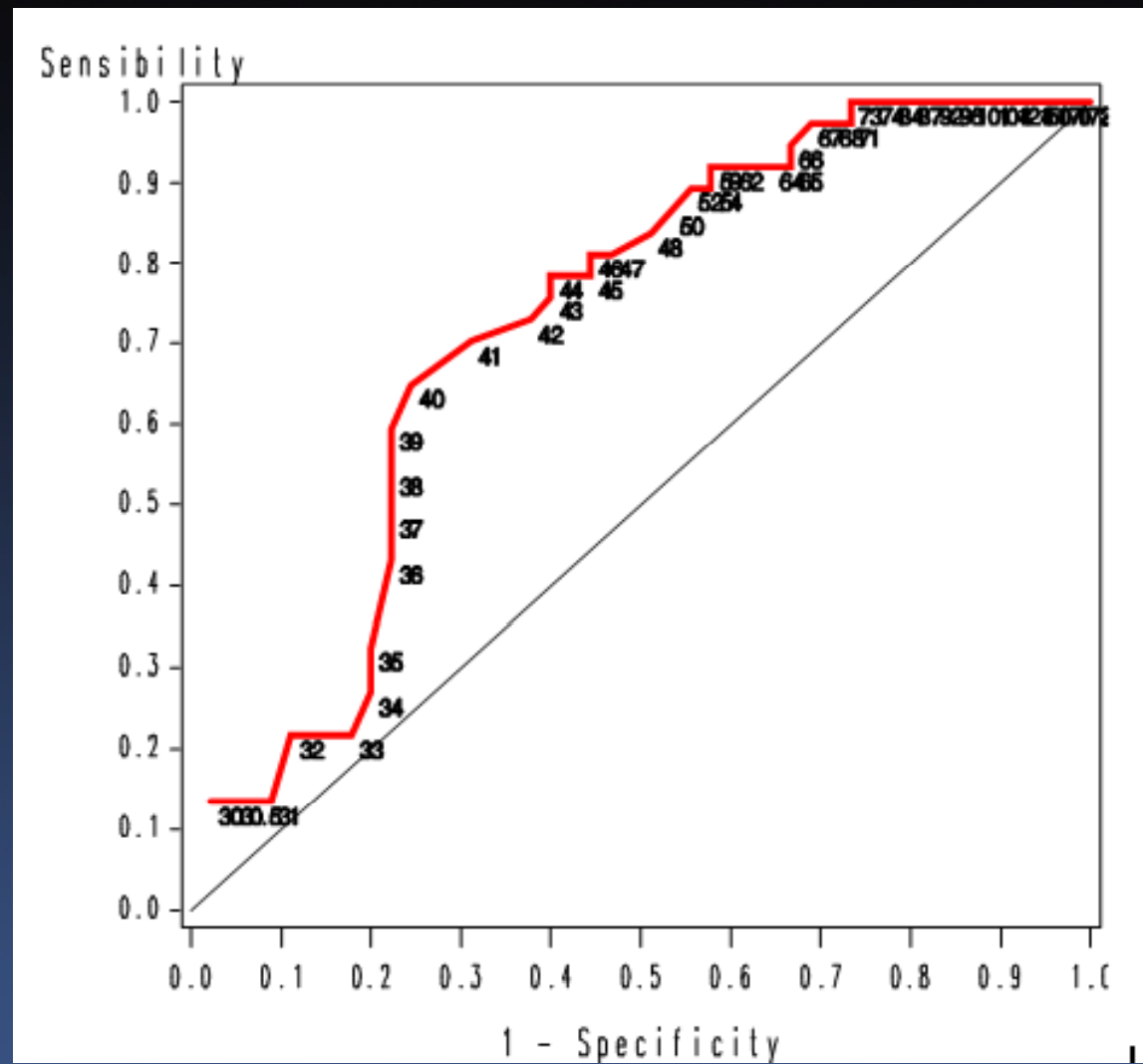




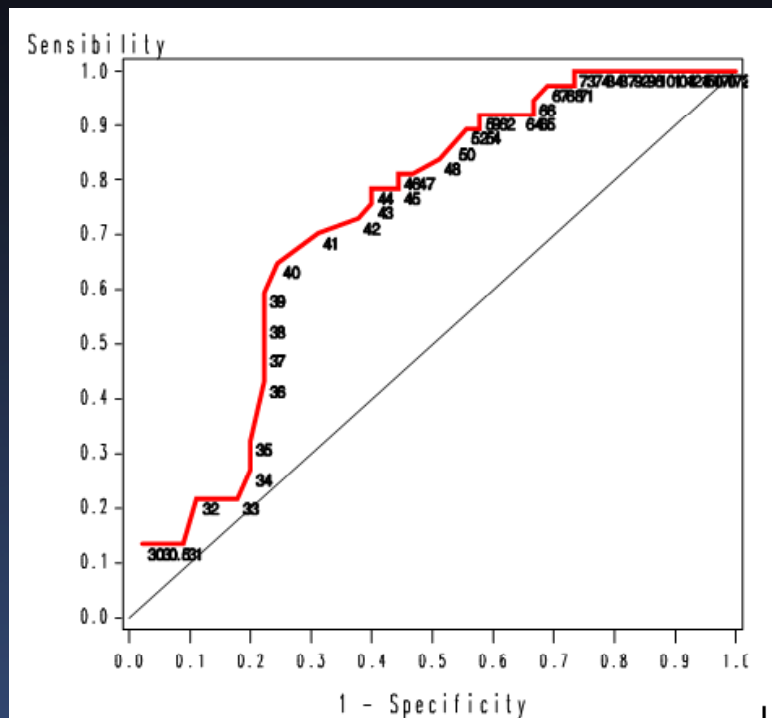
Espace ROC



Courbe ROC

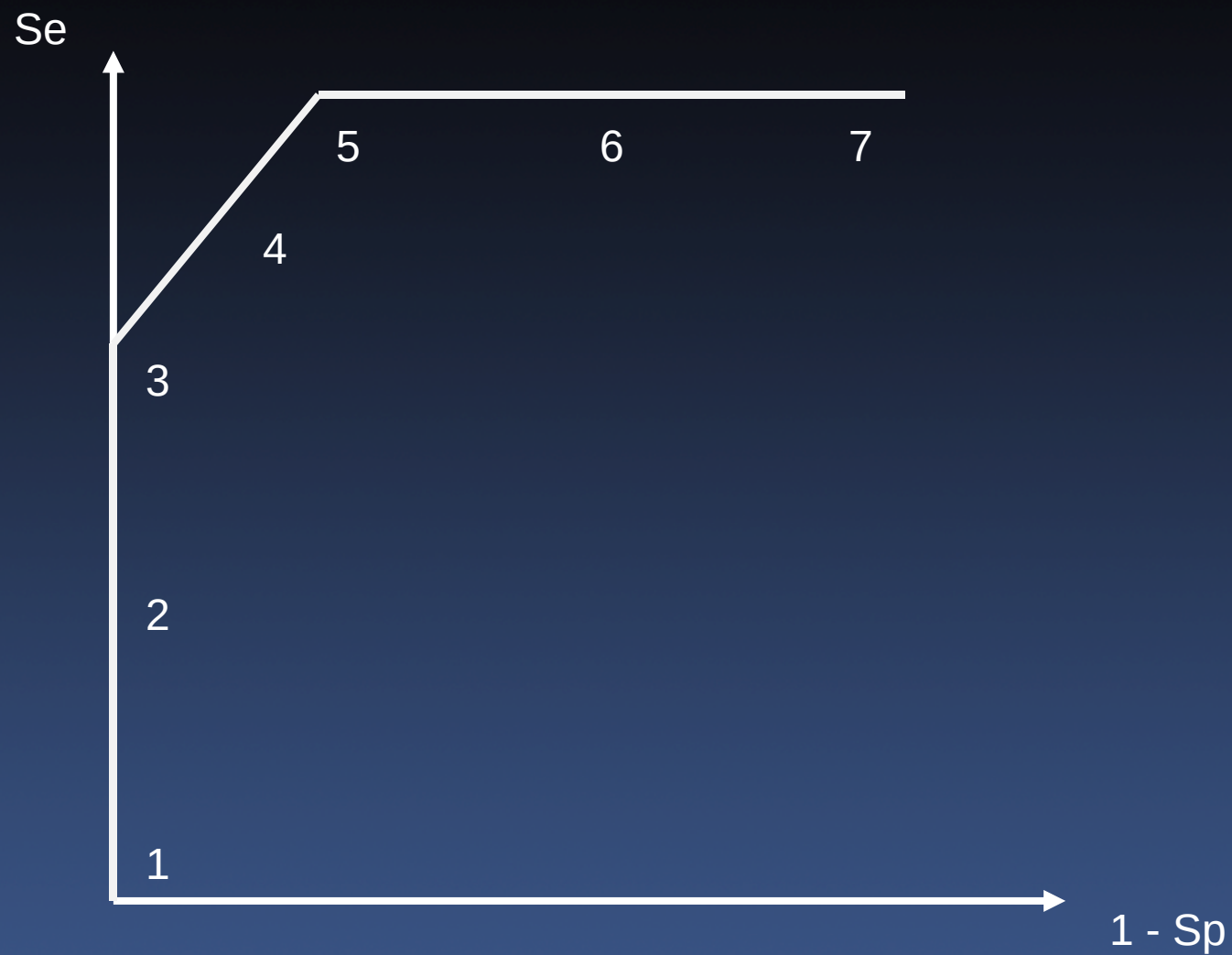


Courbe ROC



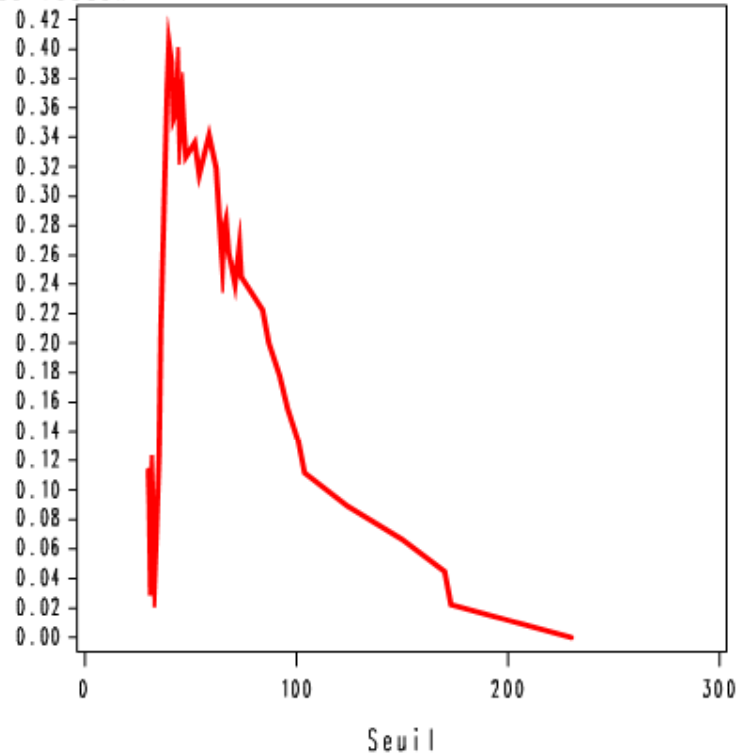
Aire sous la courbe ROC	Borne Inferieure 95	Borne Superieure 95	Z	Test de l aire sous la courbe à 50%
0.72643	0.61465	0.83820	3.51	.0004

Lecture d'une courbe ROC

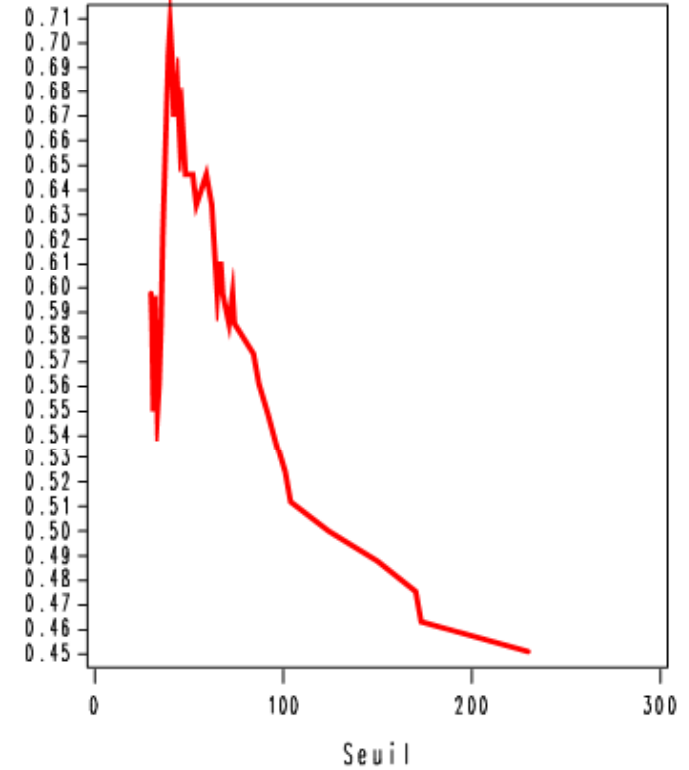


Choix du seuil

Index de Youden



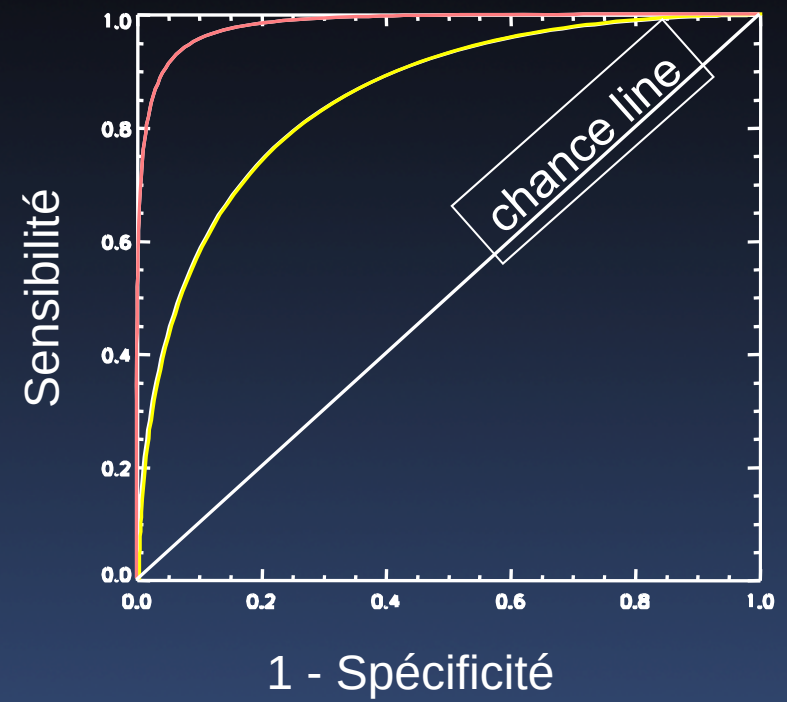
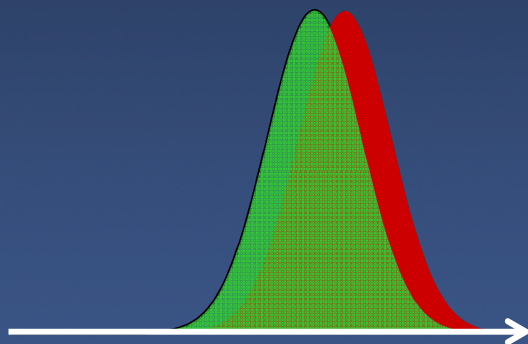
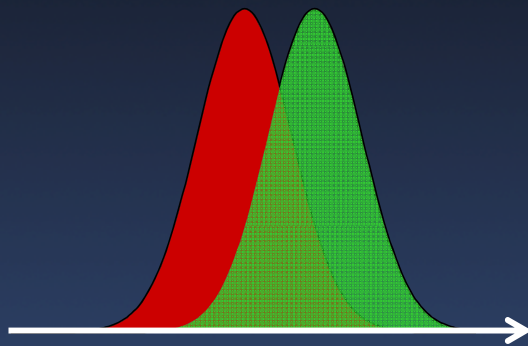
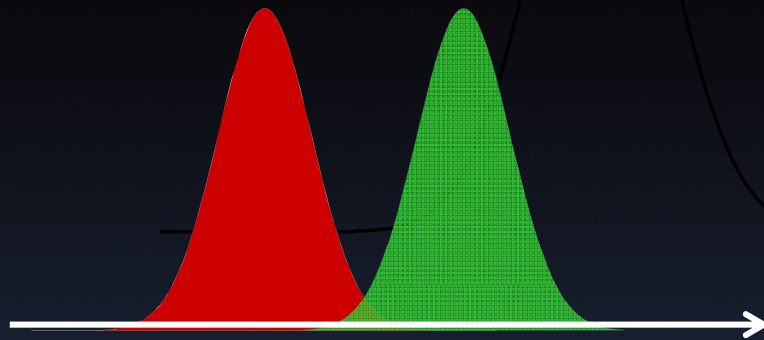
Proportion de bien classes



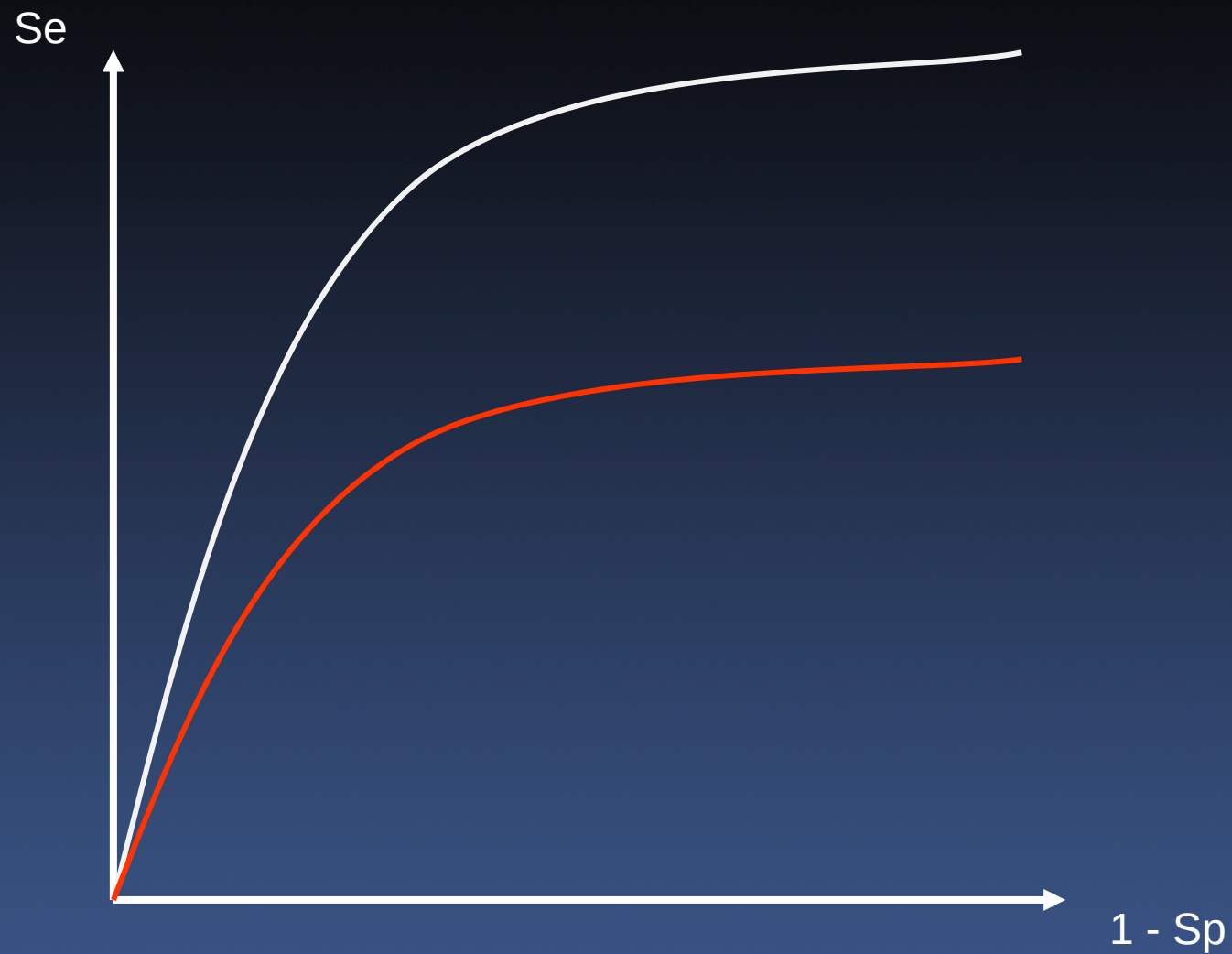
Choix du seuil

[illegible]

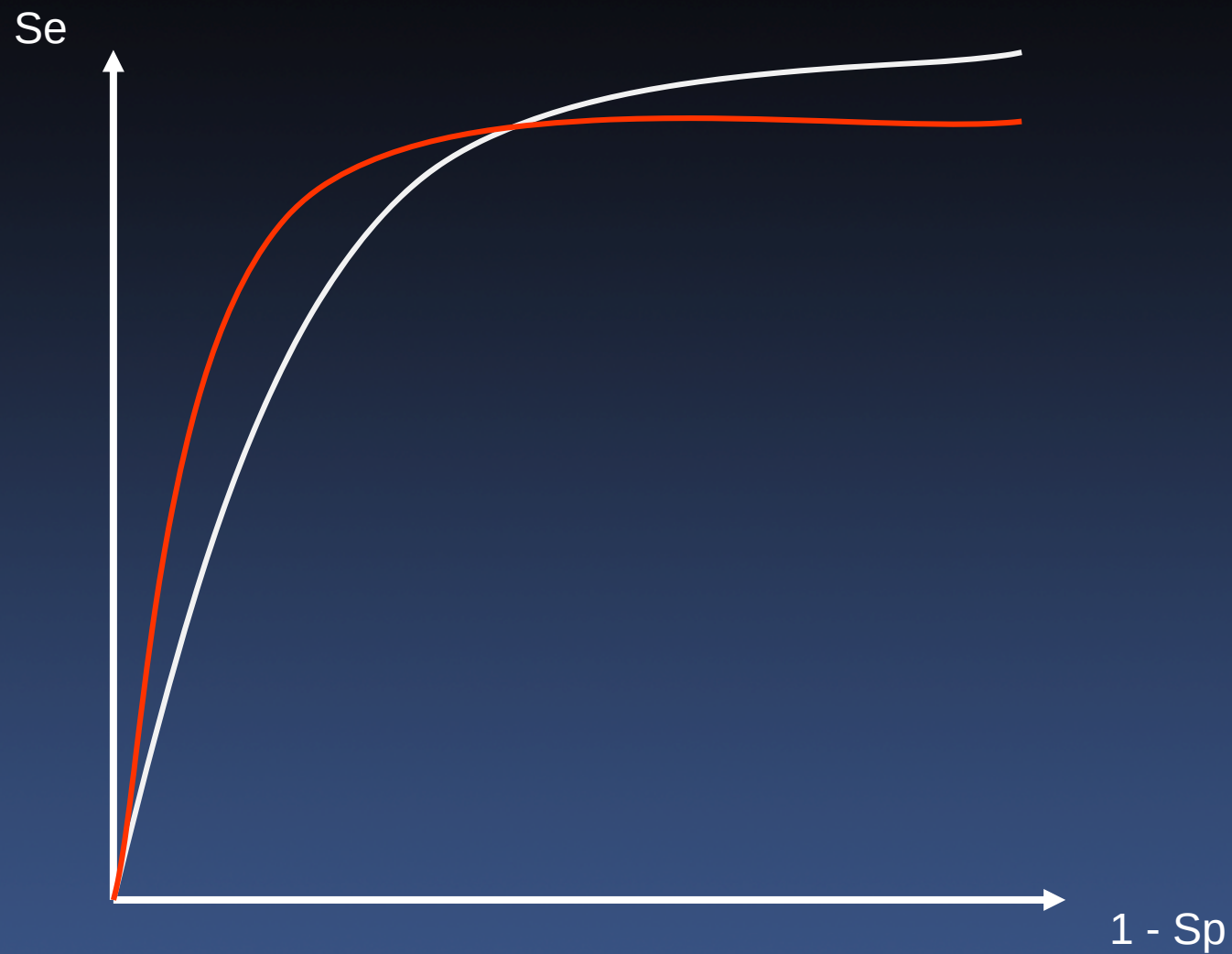
Comparaison de ROC : AUC



Comparaison de ROC : AUC



Comparaison de ROC : AUC



Conclusion

Examens diagnostiques : coût + risque

Evaluation des performances

Rapport bénéfice risque

ROC : outil de classification en optimisant le choix
du seuil

Module Image : Imagerie médicale

POST TRAITEMENT ET APPLICATIONS

Dr Denis Hoa



IMAIOS SAS
Montpellier - France



CHU Lapeyronie

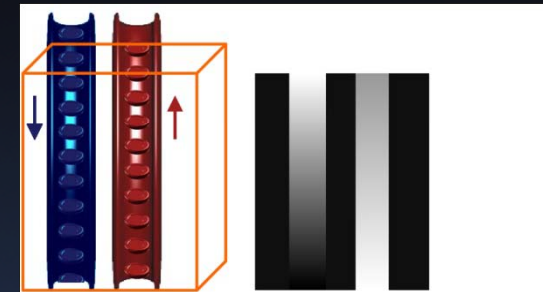
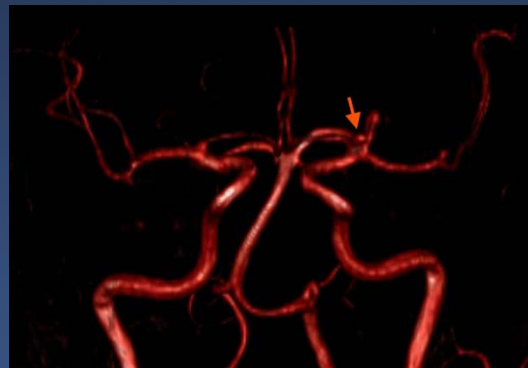
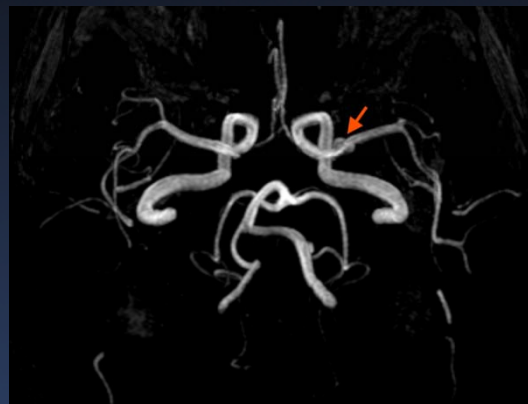


LIRMM

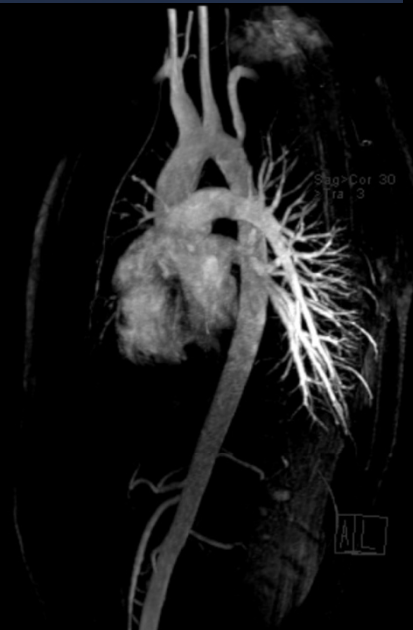
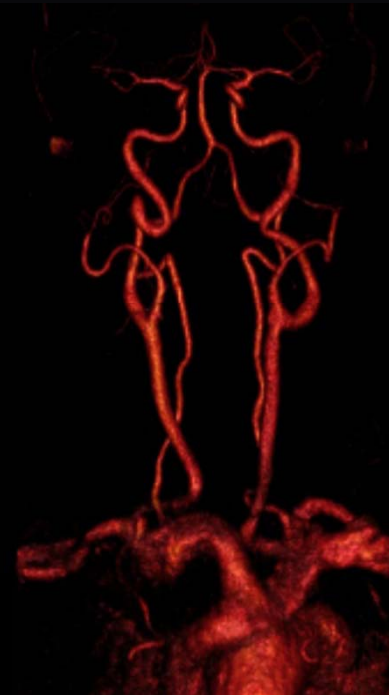
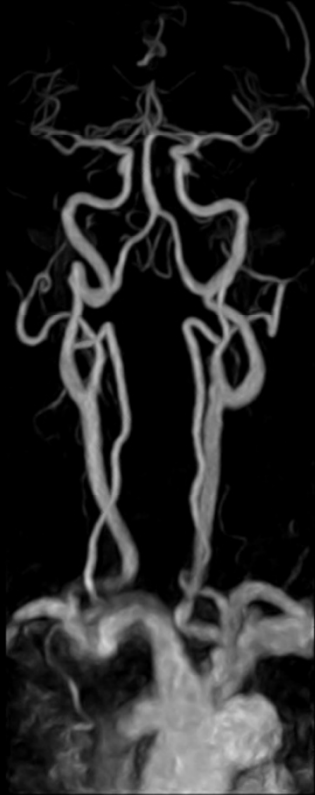
Traitement des images médicales et Applications

- Post-traitement des images médicales
- Voies de recherche
- Applications non médicales

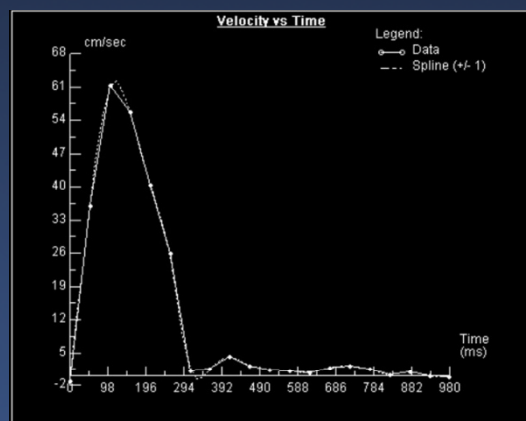
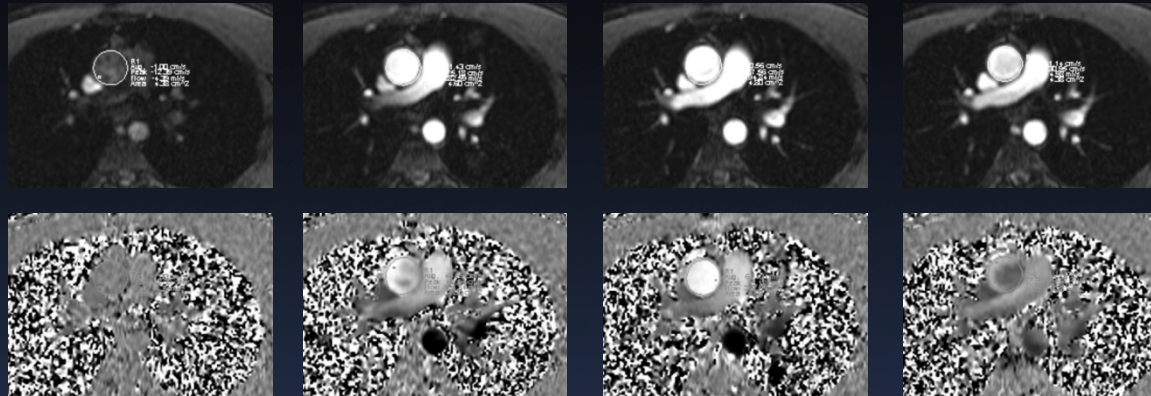
Imagerie vasculaire en IRM



Imagerie vasculaire en IRM

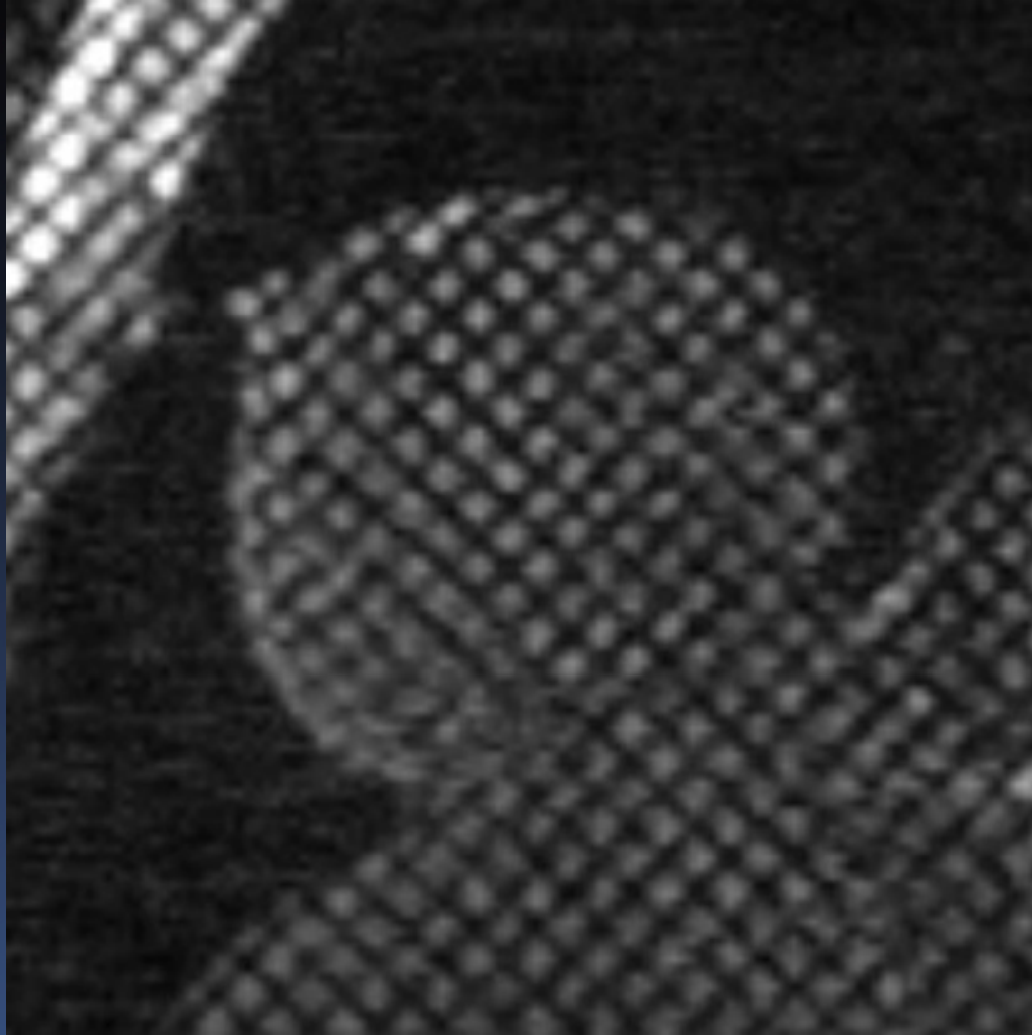


Etude des flux en IRM

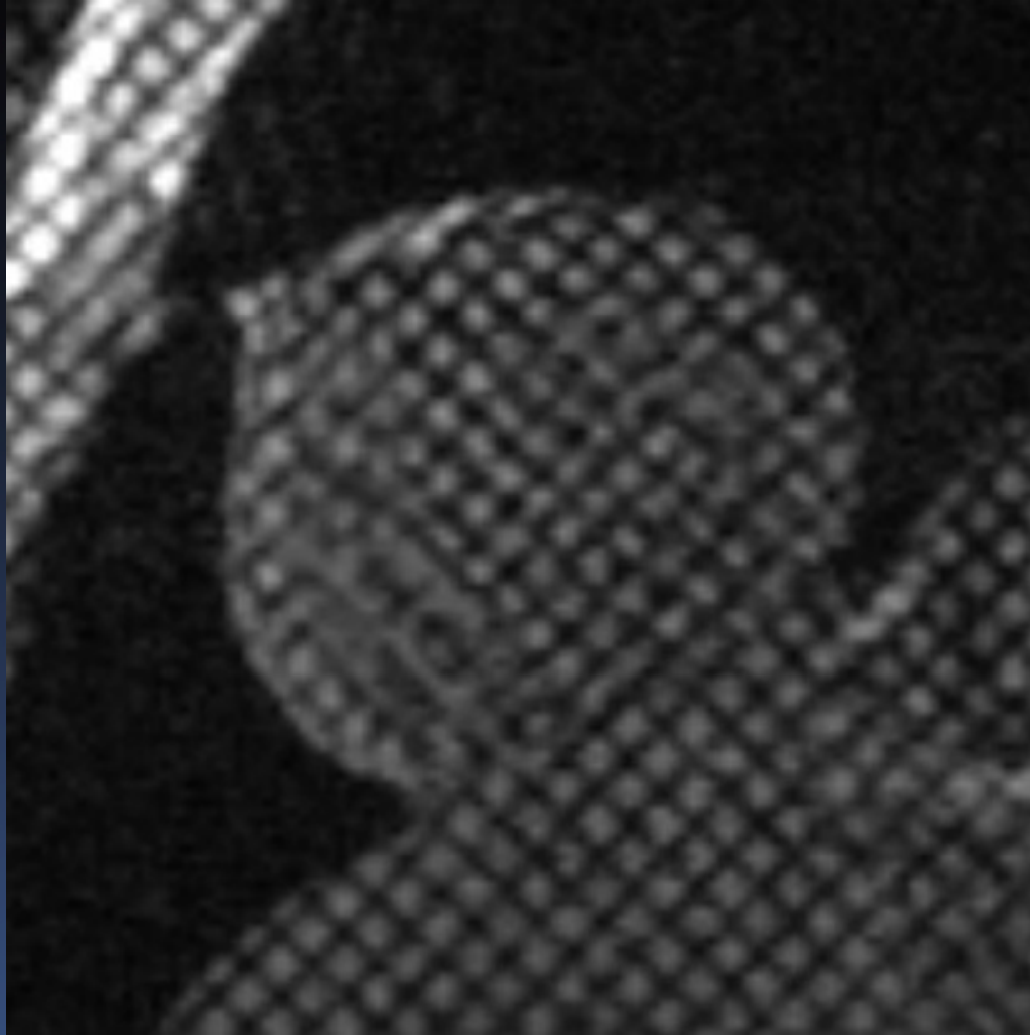


Slice Position: SP_H95.5		Region: 1
Range,ms: 0 to 979		Venc Adjustment -150 cm/sec 150 cm/sec
Body Surface Area (BSA):		---- m ²
Velocity		
Peak Velocity:	78.60	cm/sec
Average Velocity:	13.46	cm/sec
Flow		
Average Flow Over Range:	57.57	ml/sec
Average Flow Per Minute:	3.27	l/min
Forward Volume:	56.38	ml
Reverse Volume:	0.047	ml
Net Forward Volume:	56.33	ml
Net Forward Volume / BSA:	----	ml/m ²
Area		
Average Area:	4.28	cm ²
Minimum Area:	3.70	cm ²
Maximum Area:	4.80	cm ²

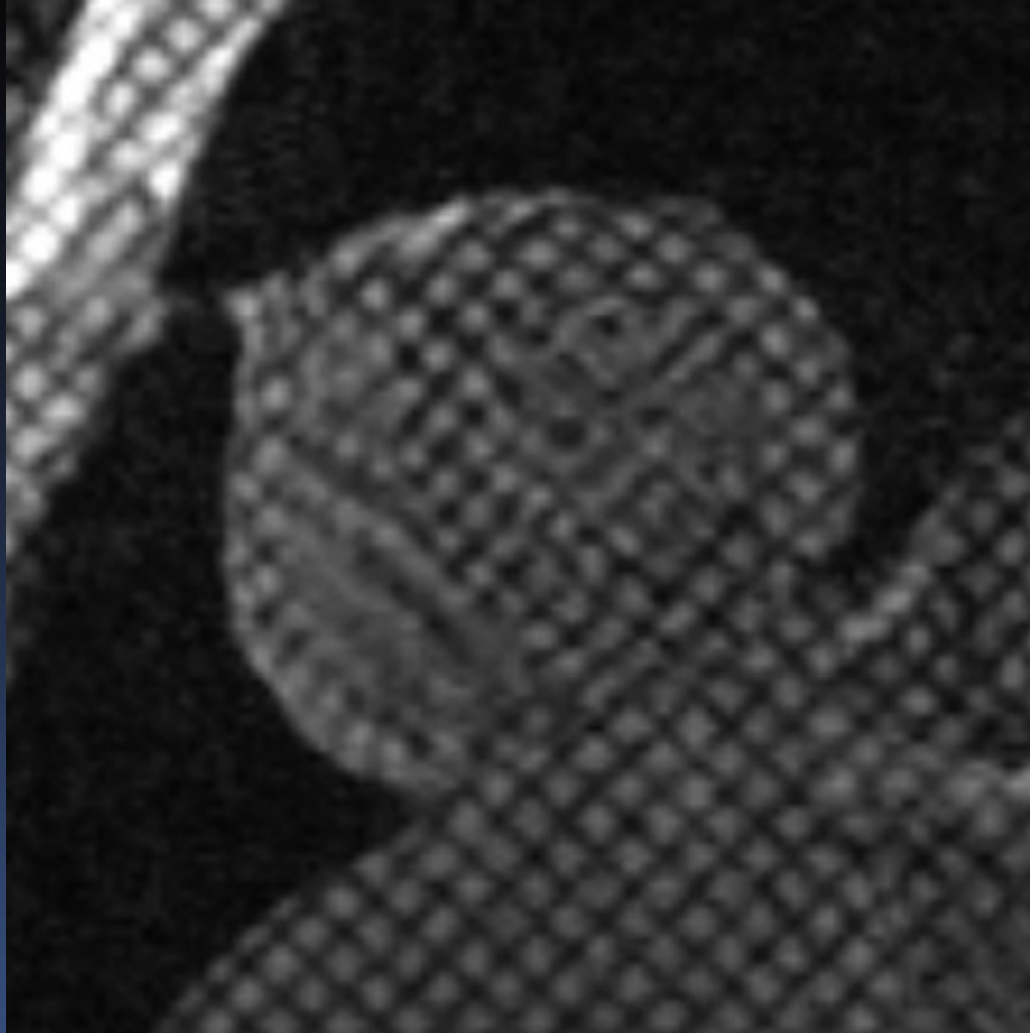
Etude de la cinétique cardiaque en IRM



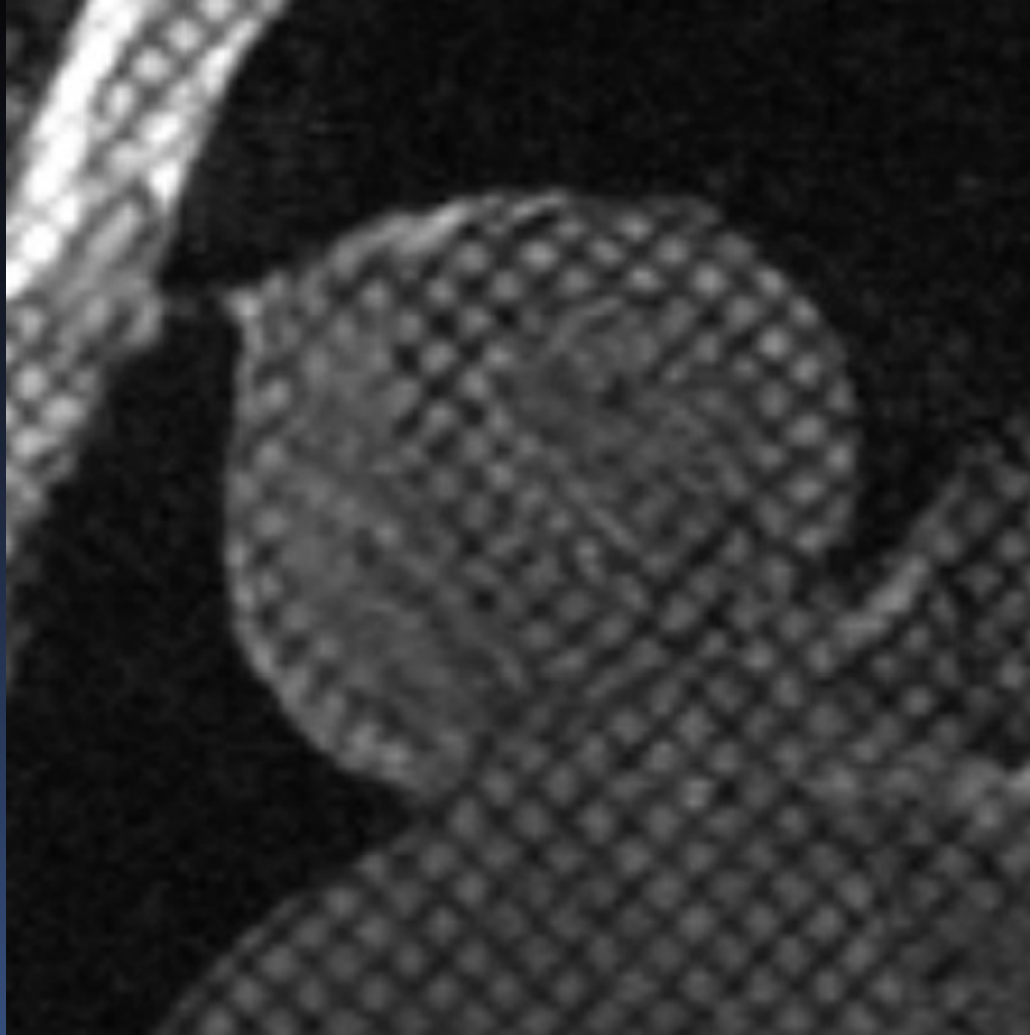
Etude de la cinétique cardiaque en IRM



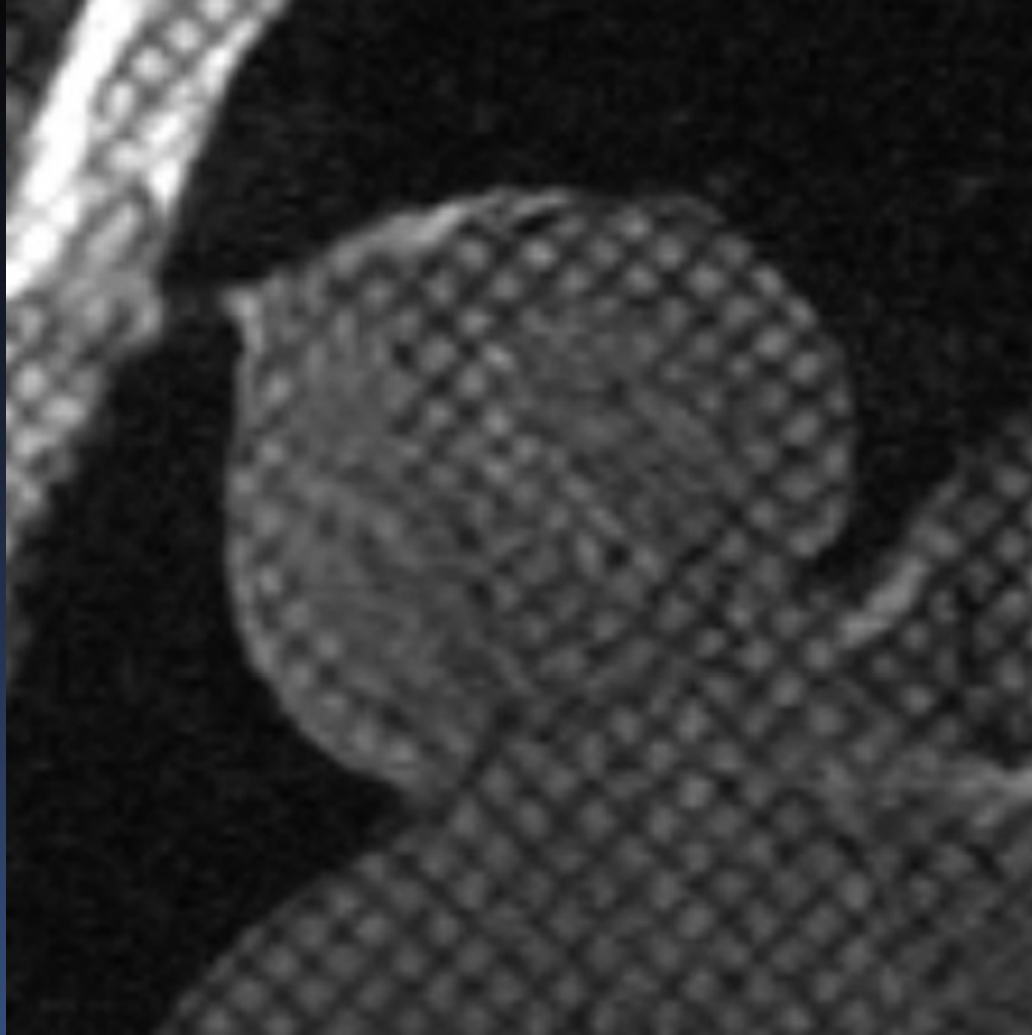
Etude de la cinétique cardiaque en IRM



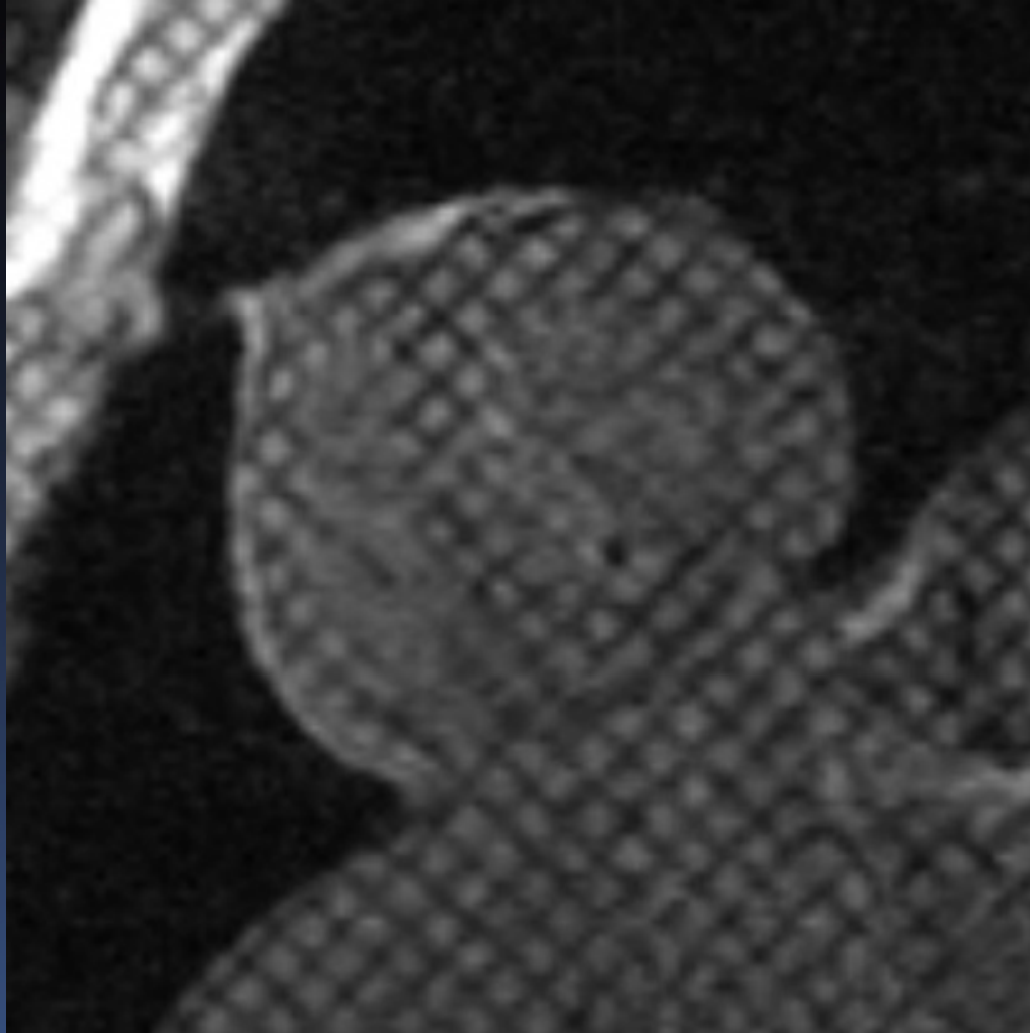
Etude de la cinétique cardiaque en IRM



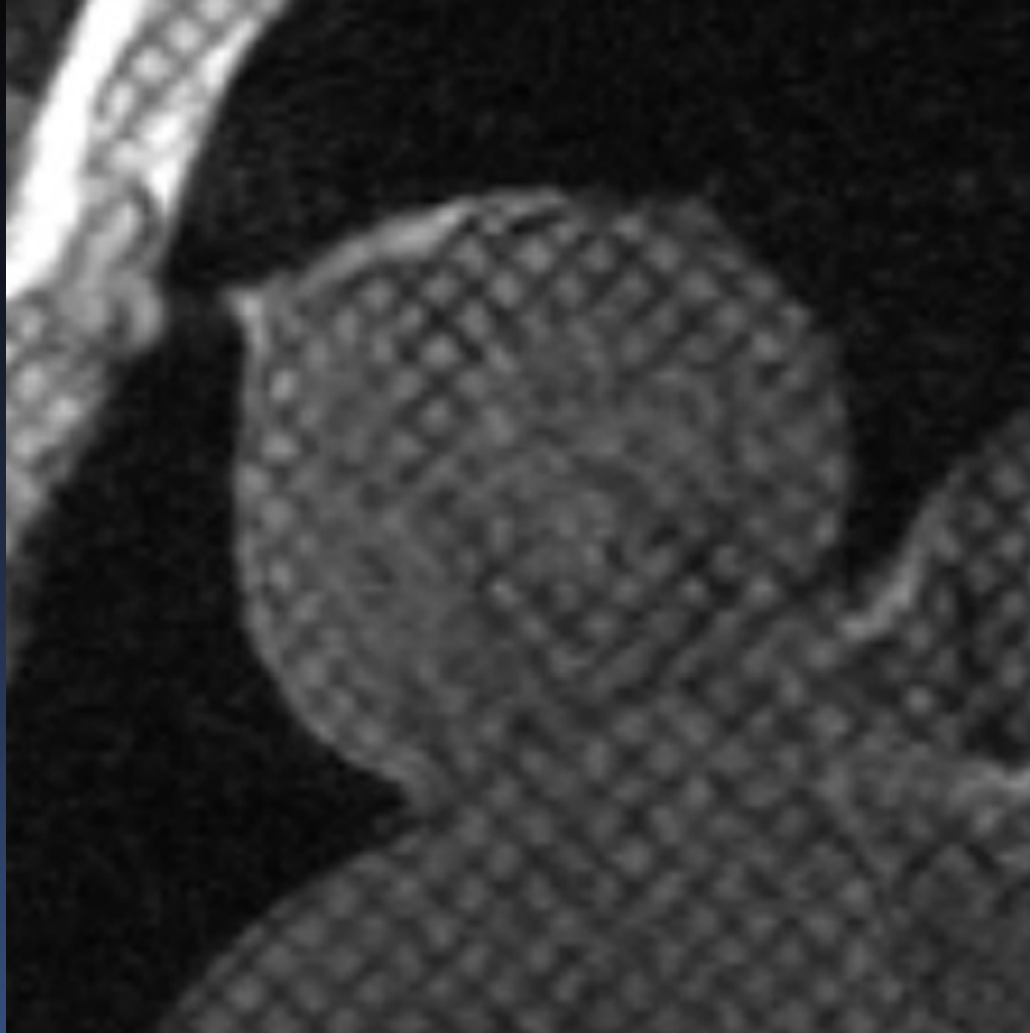
Etude de la cinétique cardiaque en IRM



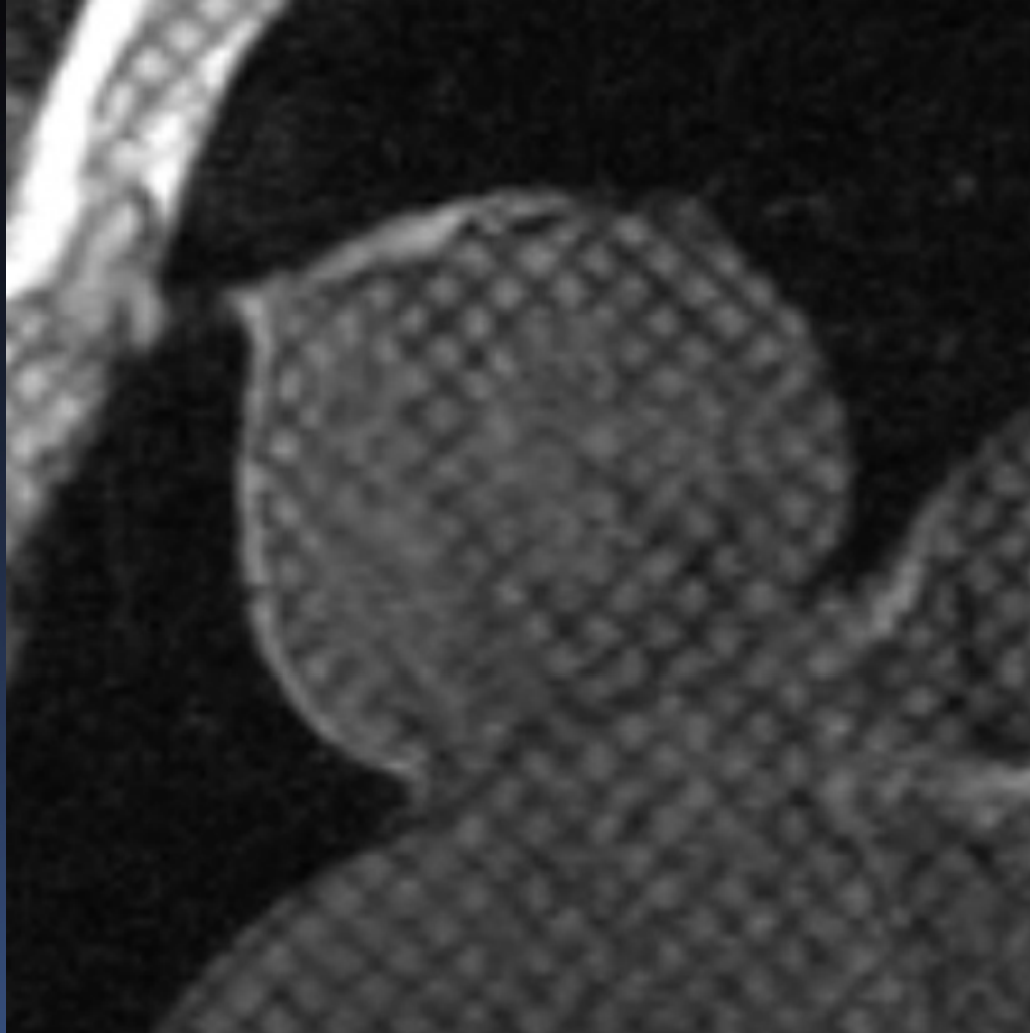
Etude de la cinétique cardiaque en IRM



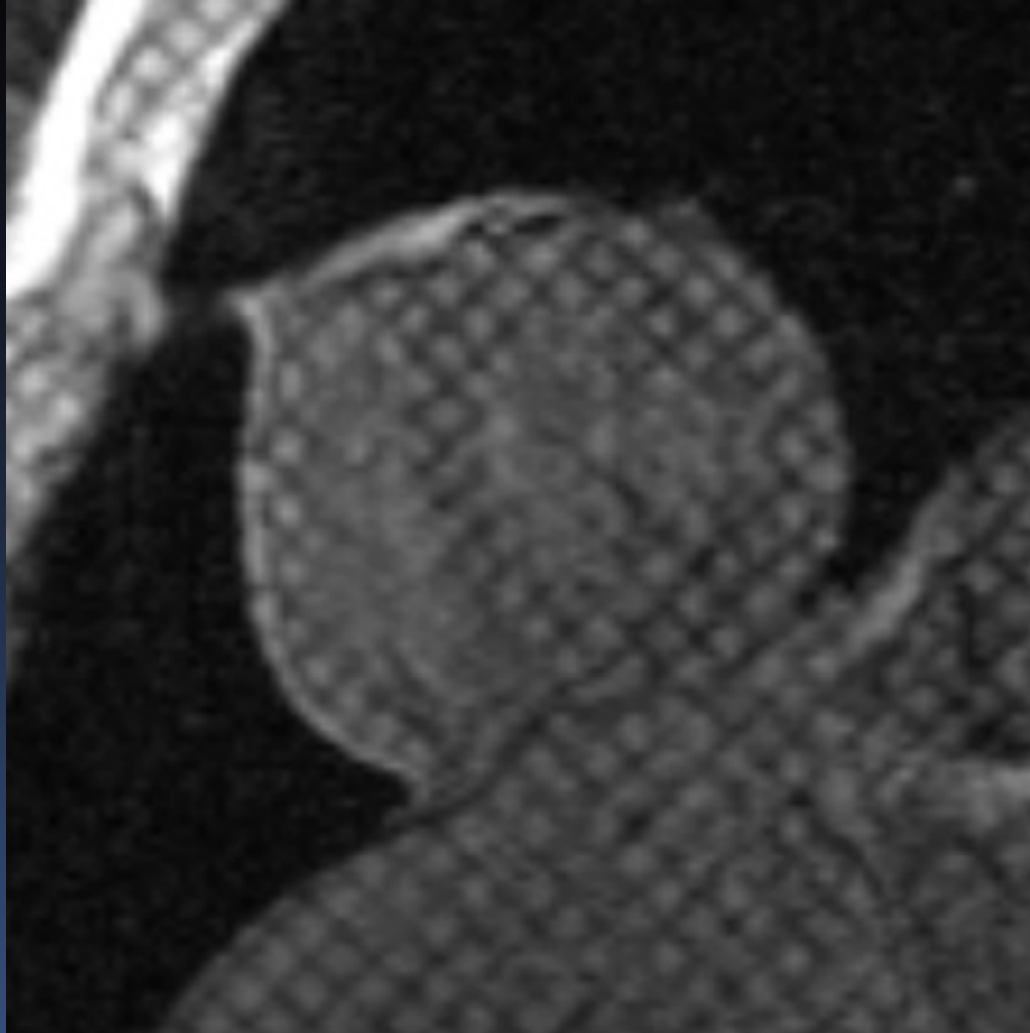
Etude de la cinétique cardiaque en IRM



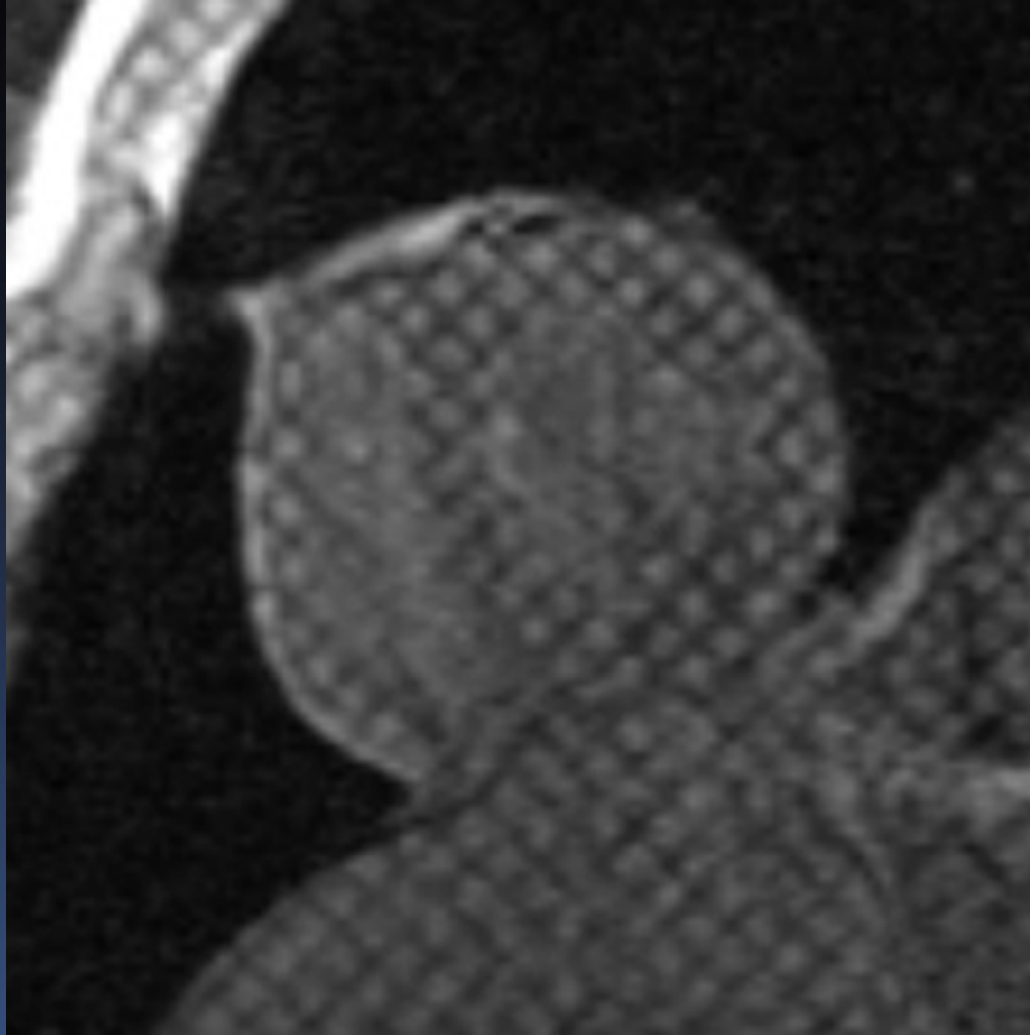
Etude de la cinétique cardiaque en IRM



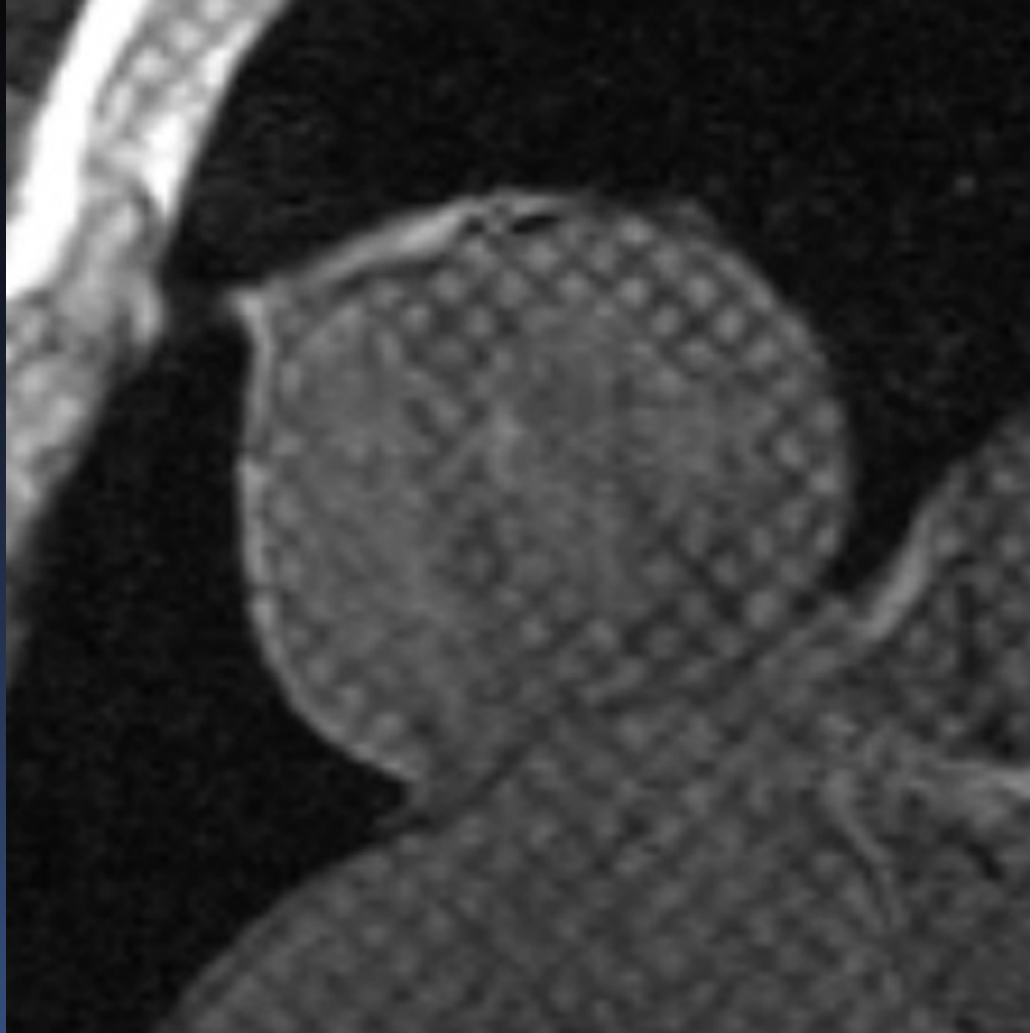
Etude de la cinétique cardiaque en IRM



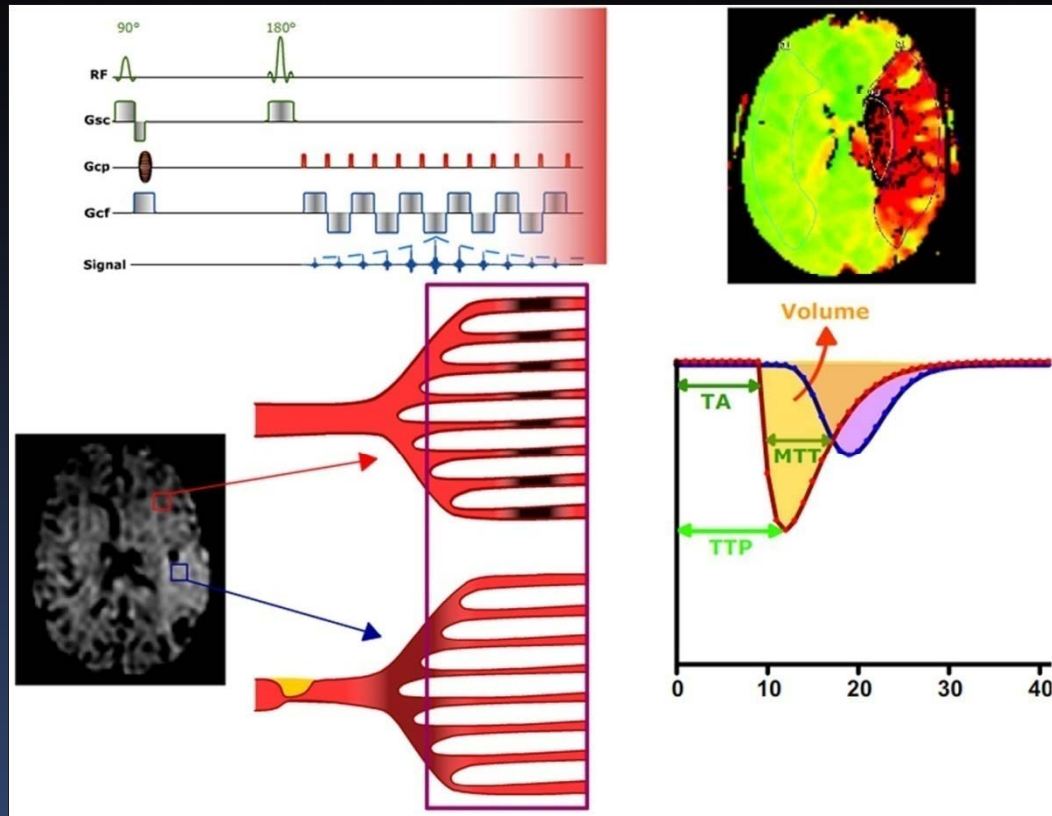
Etude de la cinétique cardiaque en IRM



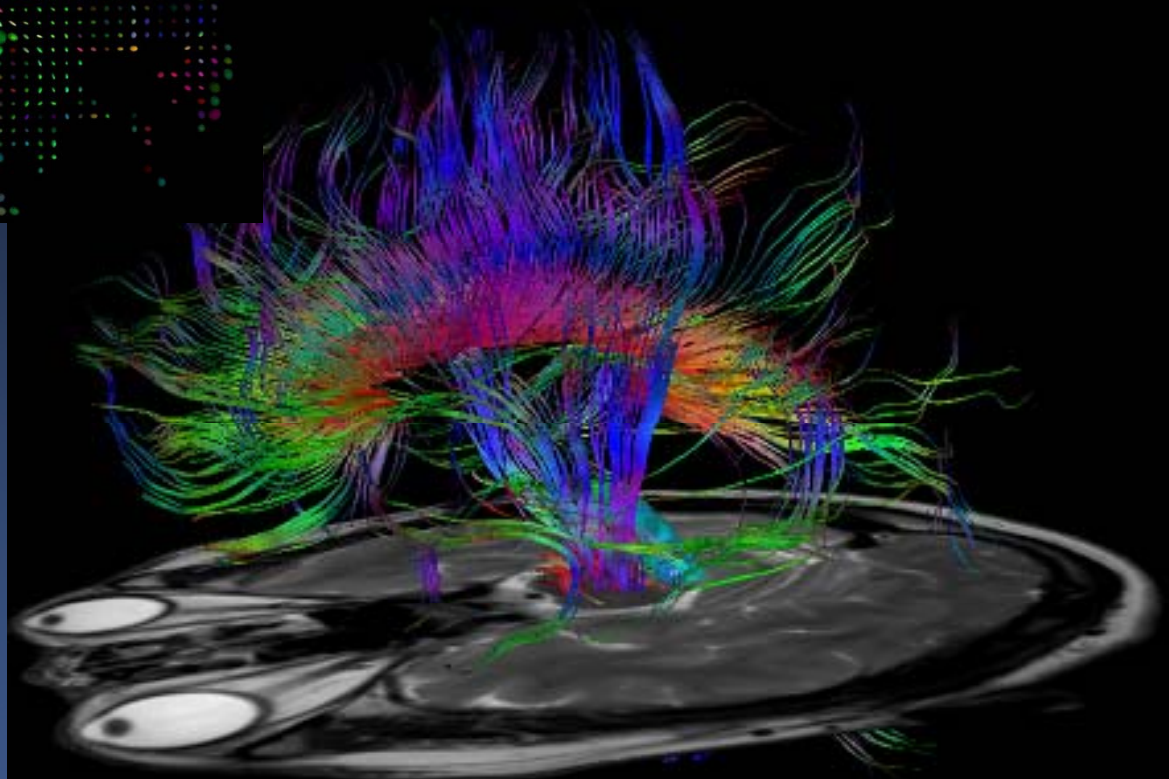
Etude de la cinétique cardiaque en IRM



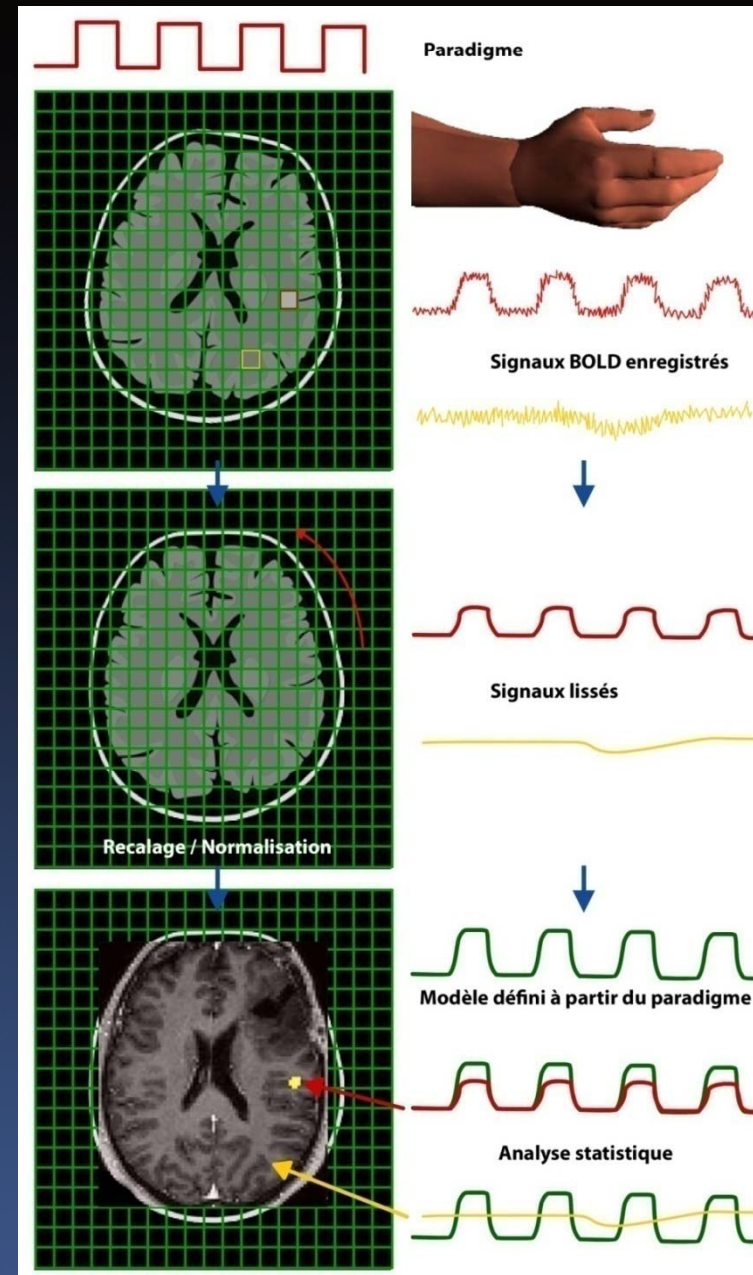
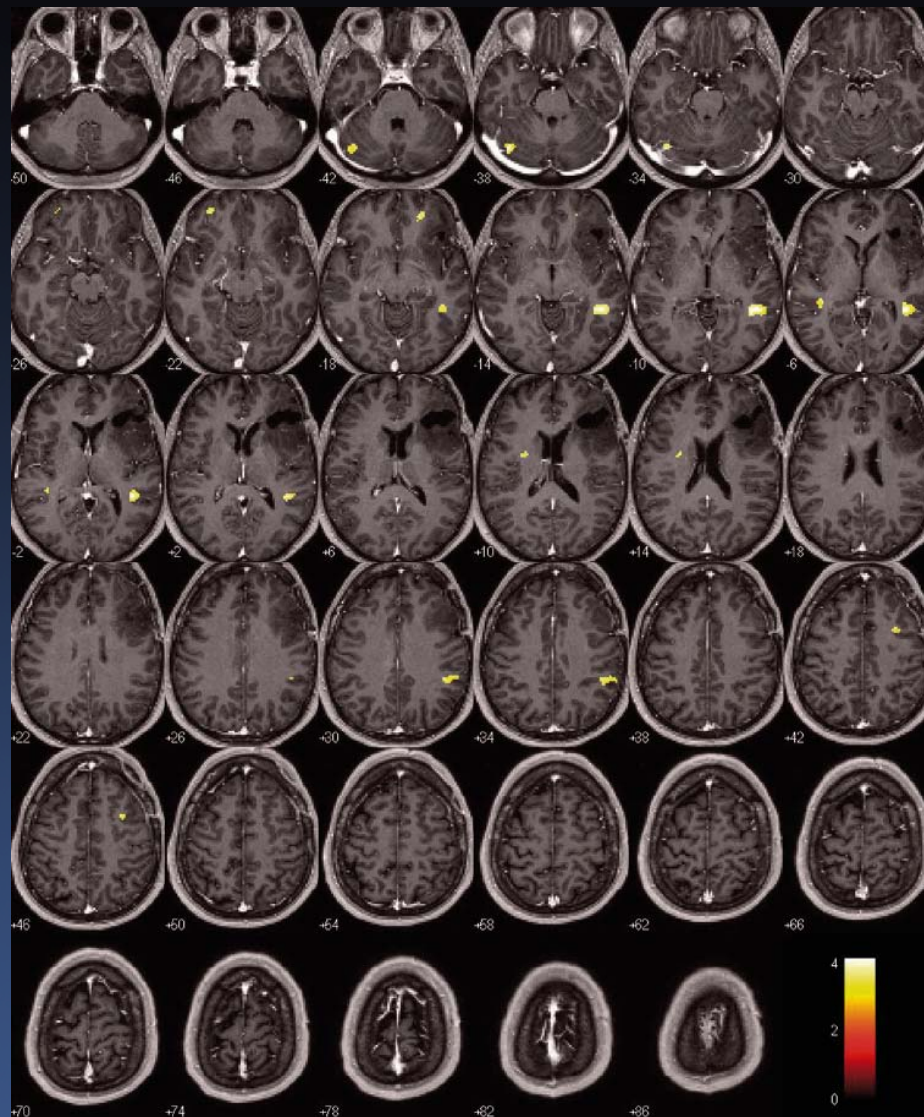
Imagerie de la perfusion cérébrale en IRM



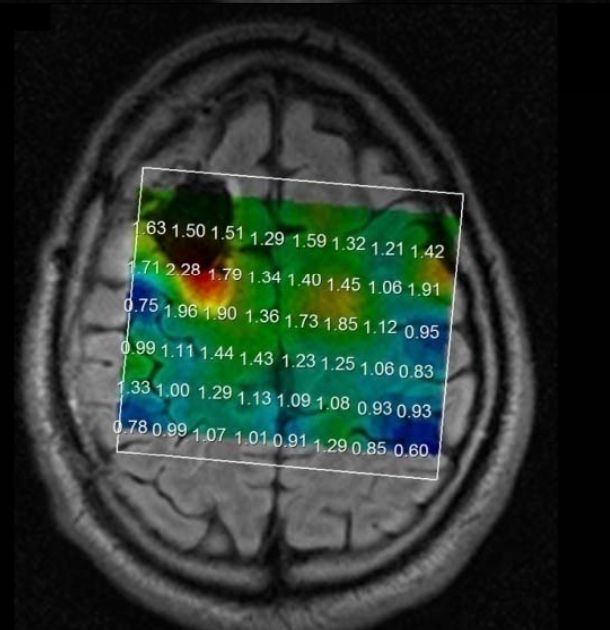
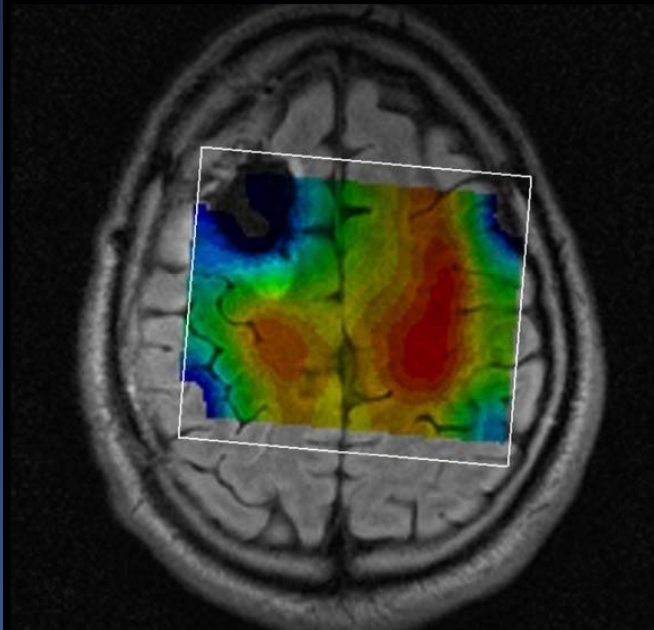
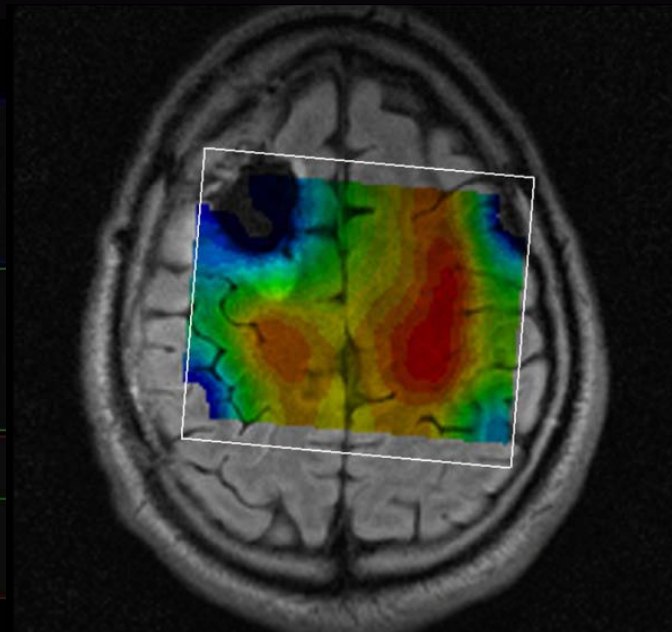
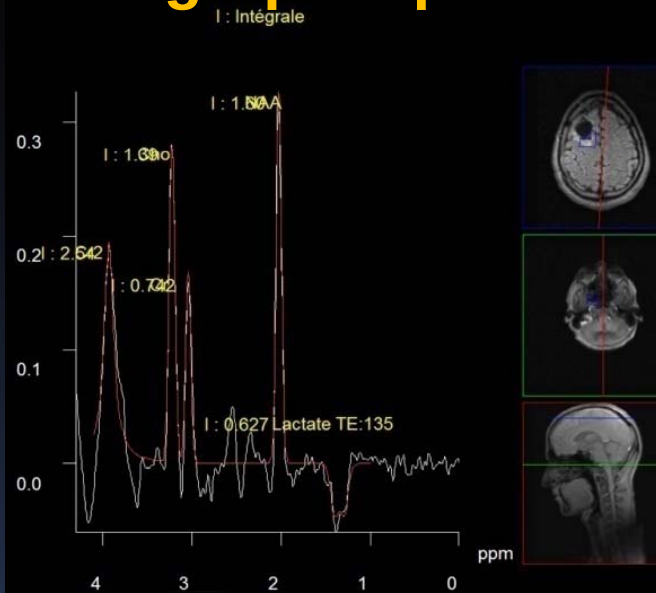
Imagerie du tenseur de diffusion en IRM



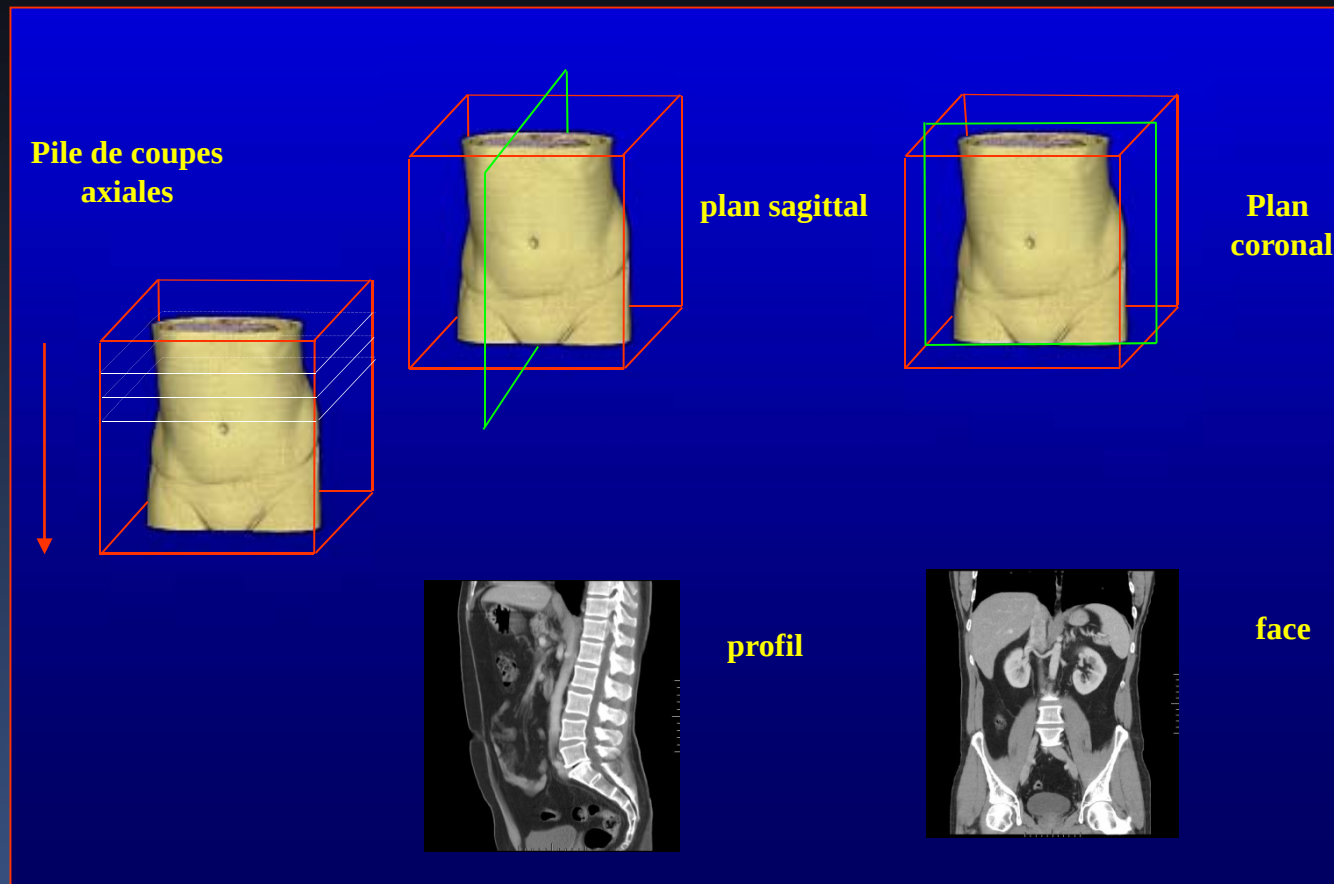
Imagerie fonctionnelle en IRM



Spectrographie par RM



Reformatage TDM



Reformatage TDM



Axiale

Coronale



Sagittale

Oblique



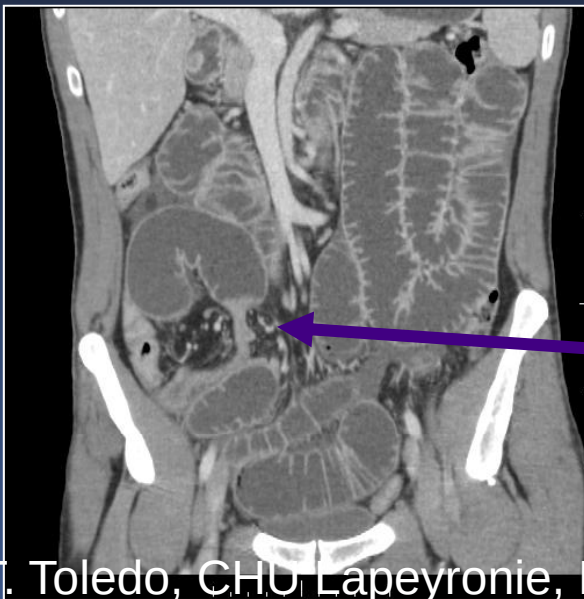
Reformatage TDM



Occlusion
mécanique
du grêle



Mise en évidence
d'une bride à
l'aide des vues:

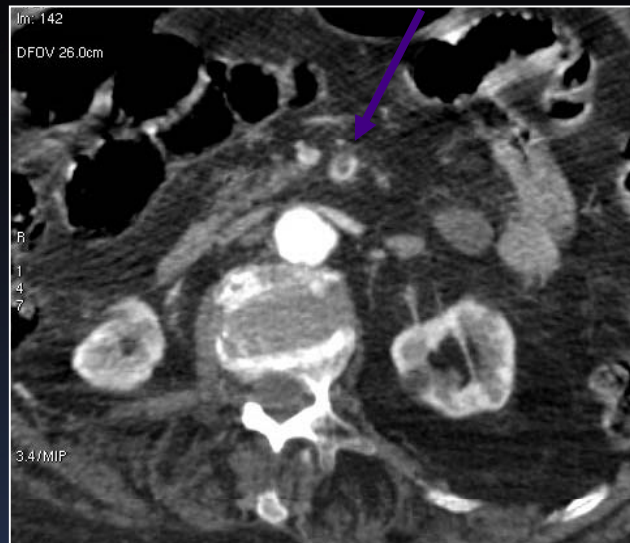


coronale
et

sagittale



Reformatage TDM

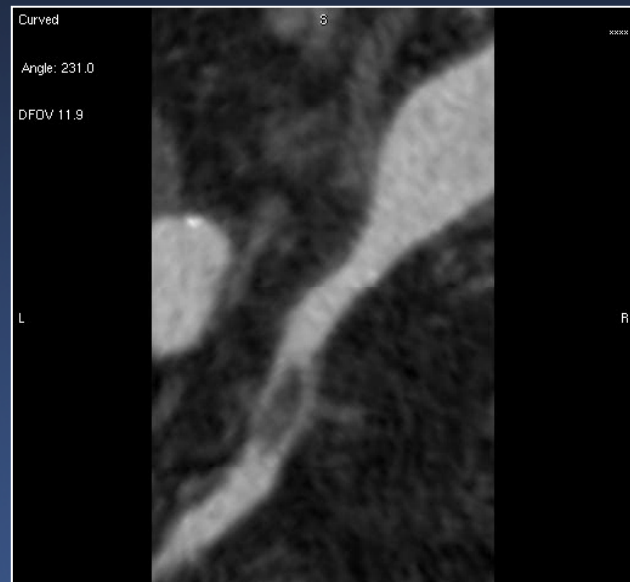


Axiale

Sagittale
Oblique

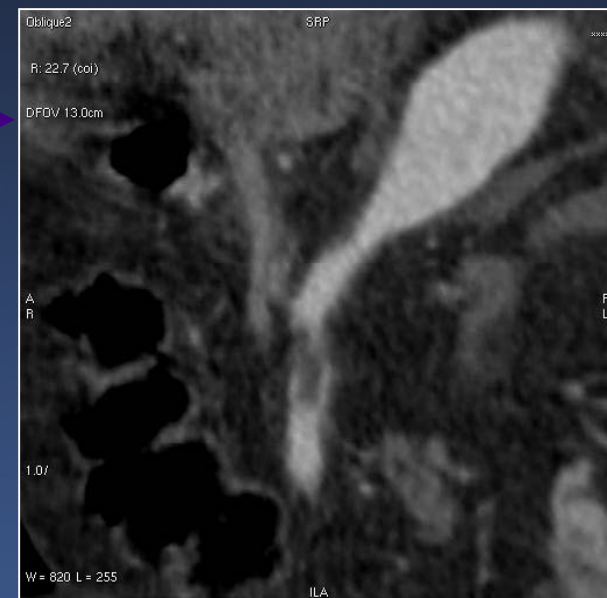


Embol mésentérique



Curviligne

Coronale
Oblique



Reformatage TDM

Appendicite aiguë



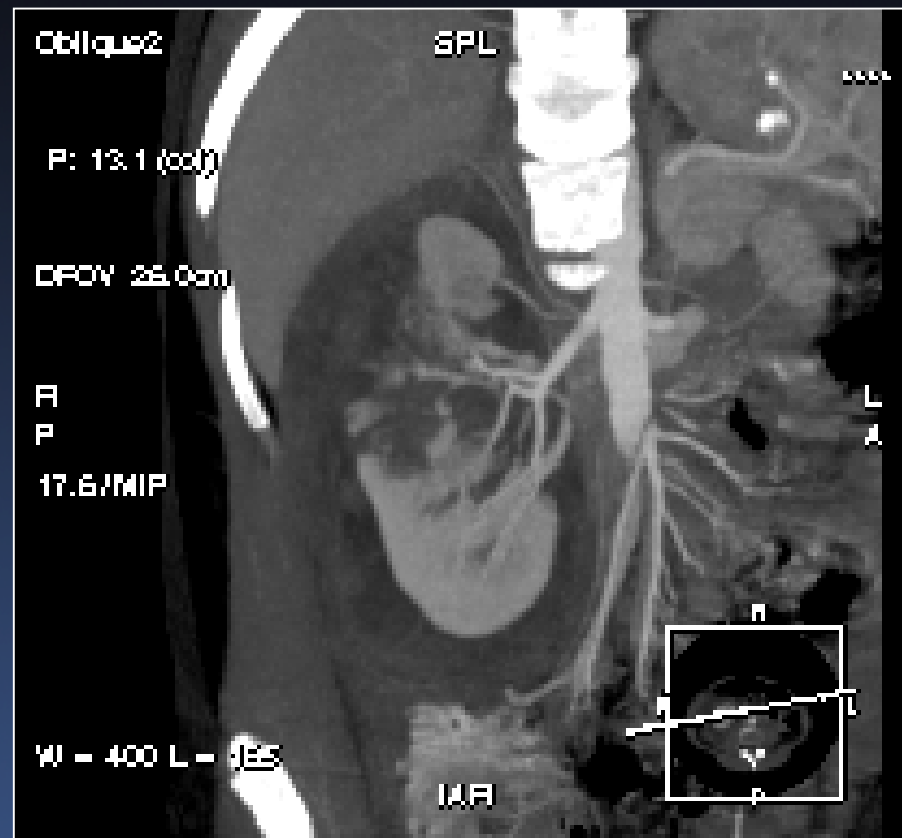
Vue A



Vue B résultante

Reformatage TDM

Trauma du rein :
vue en double oblique.

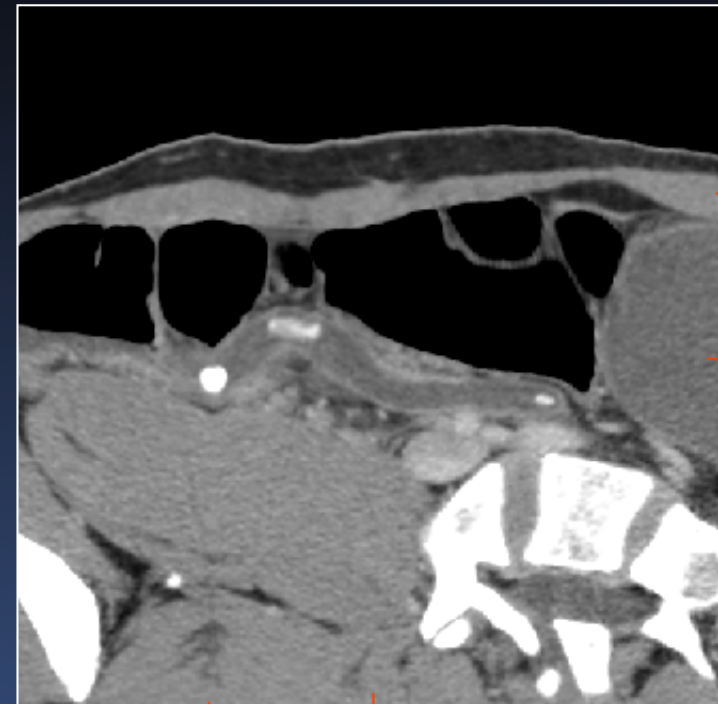
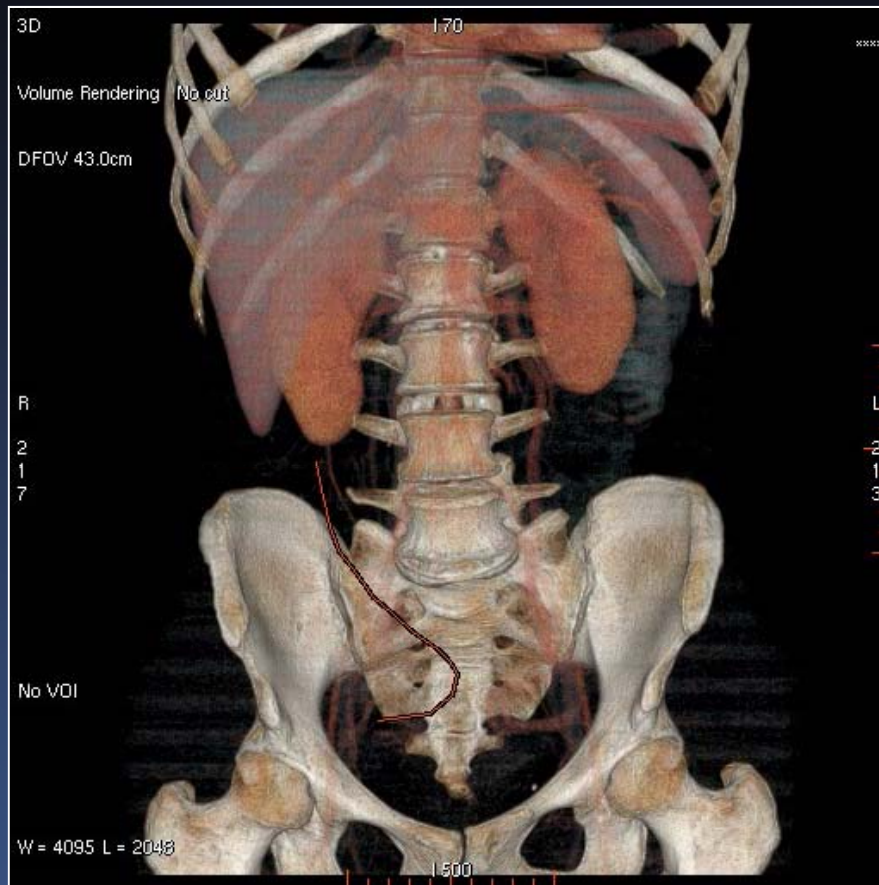


Occlusion mécanique.



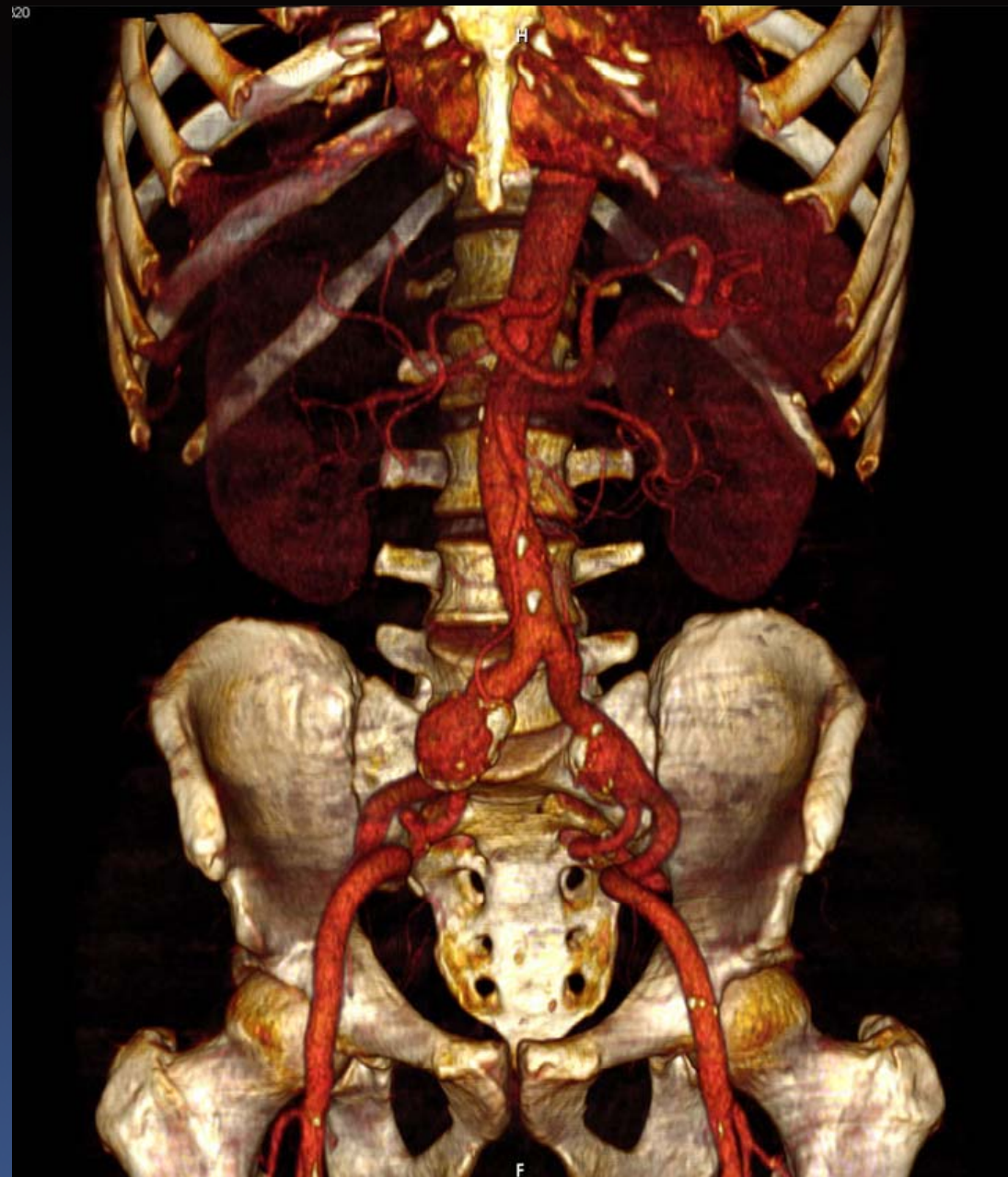
Reformatage TDM

Reformatage curviligne Appendicite aiguë.



**Structures tubulaires
tortueuses.**

Volume Rendering



Volume Rendering



Anévrisme
de l'artère
splénique

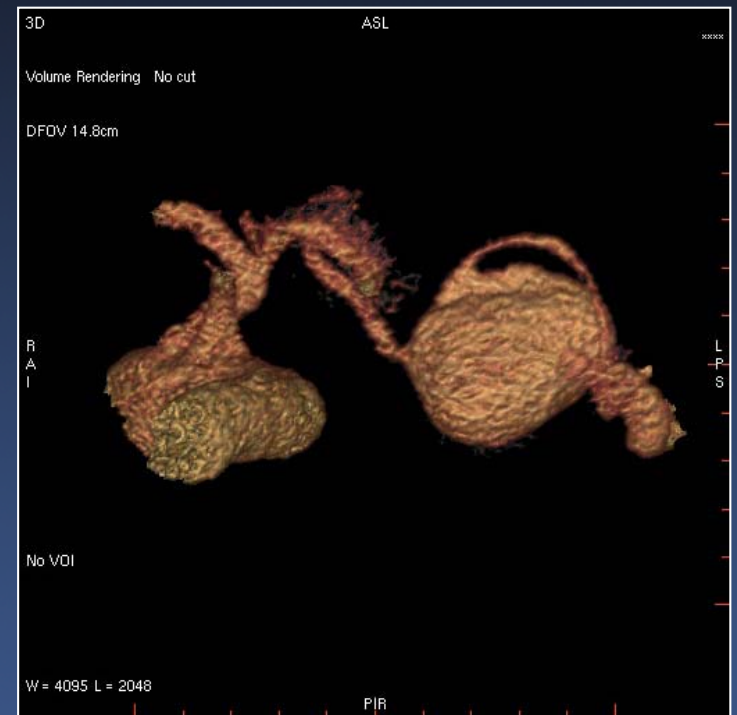
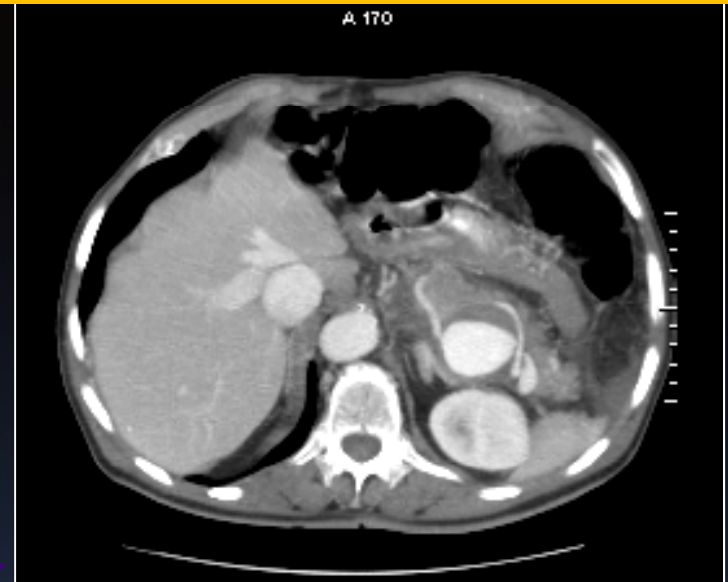
MIP

Axiale

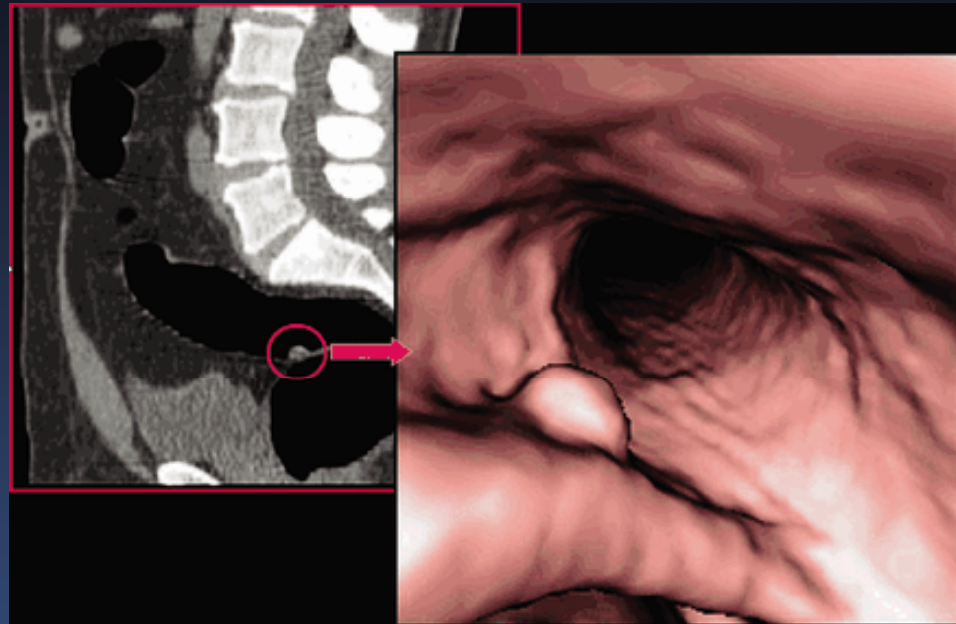
Oblique

Coronale

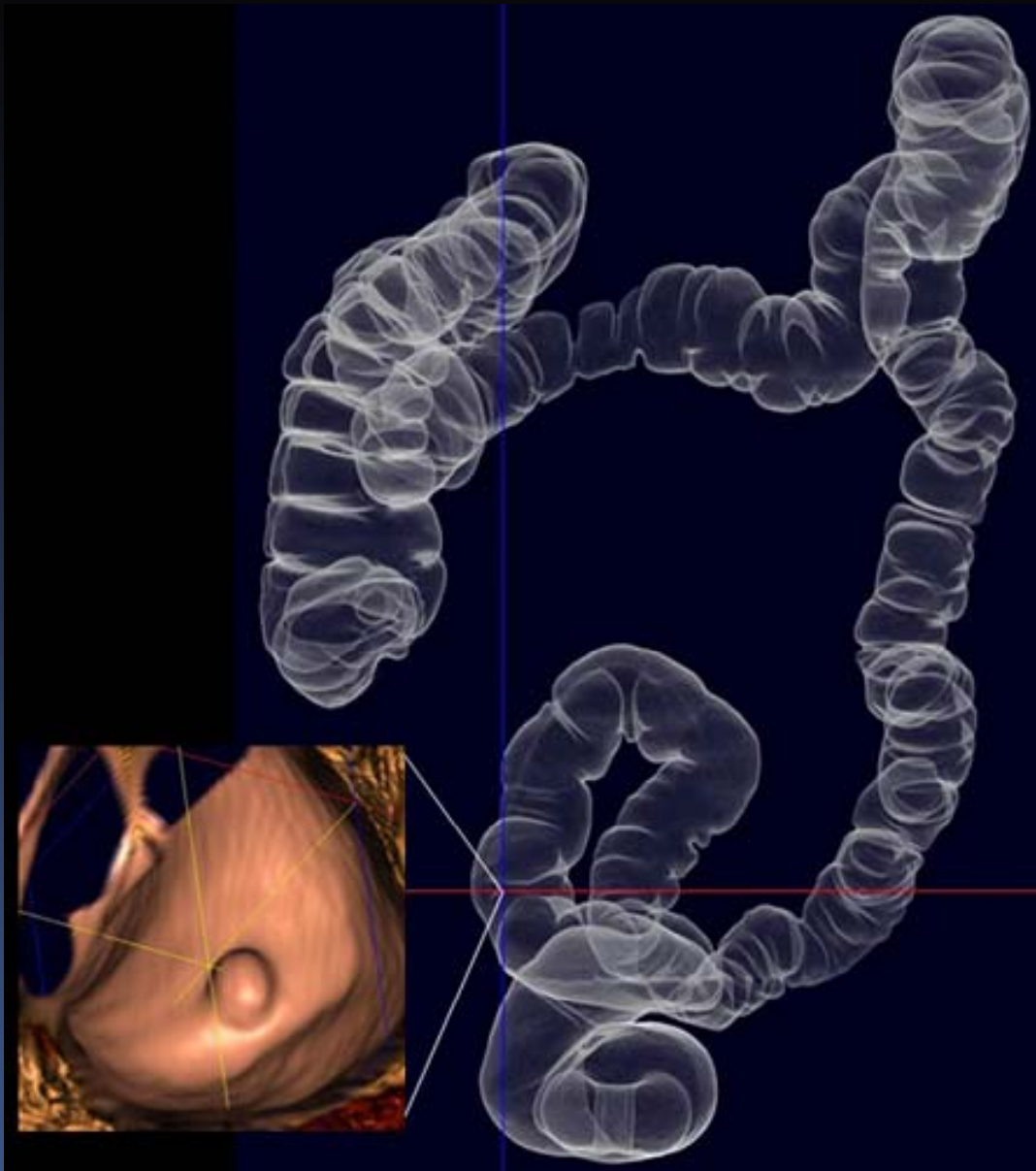
VR
ciné



3D surfacique et endoscopie virtuelle



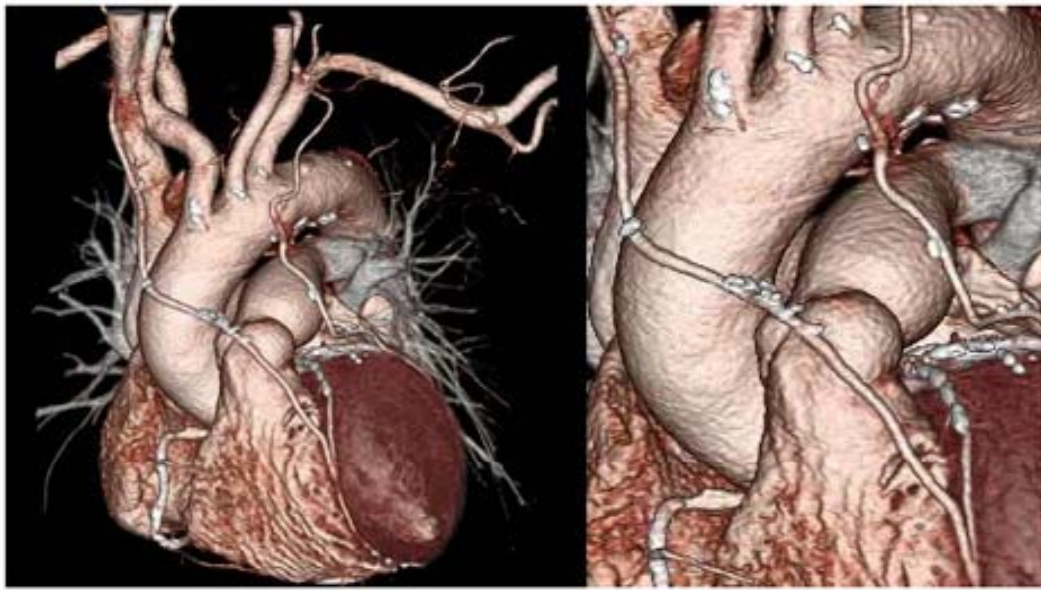
Coloscopie virtuelle



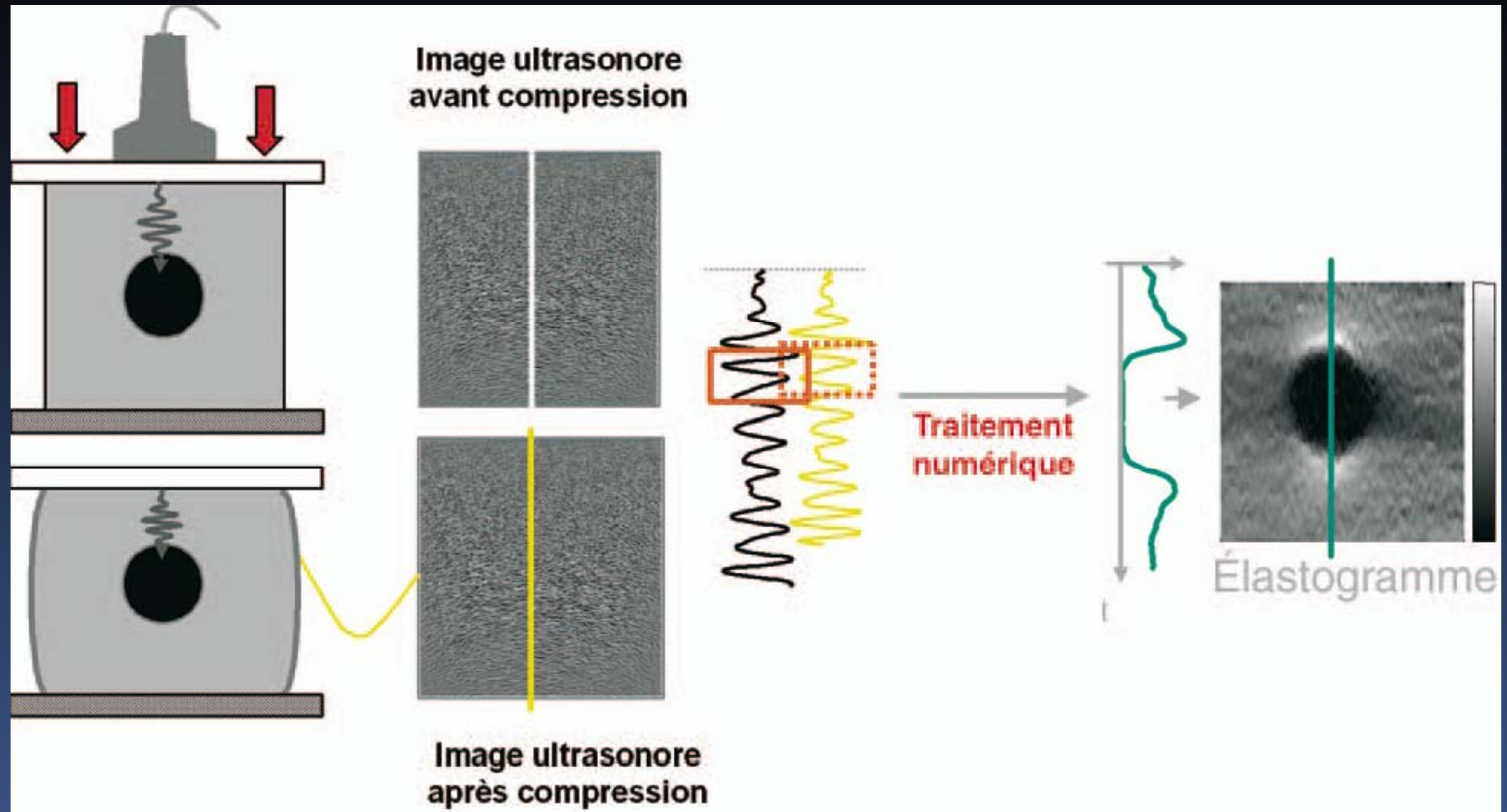
Recherche en imagerie médicale

- Acquisition : + précis, + rapide, - délétère
- Post - traitement : 3D / 4D, analyse automatisée
- Interprétation : CAD
- Applications : Réalité augmentée, robotique

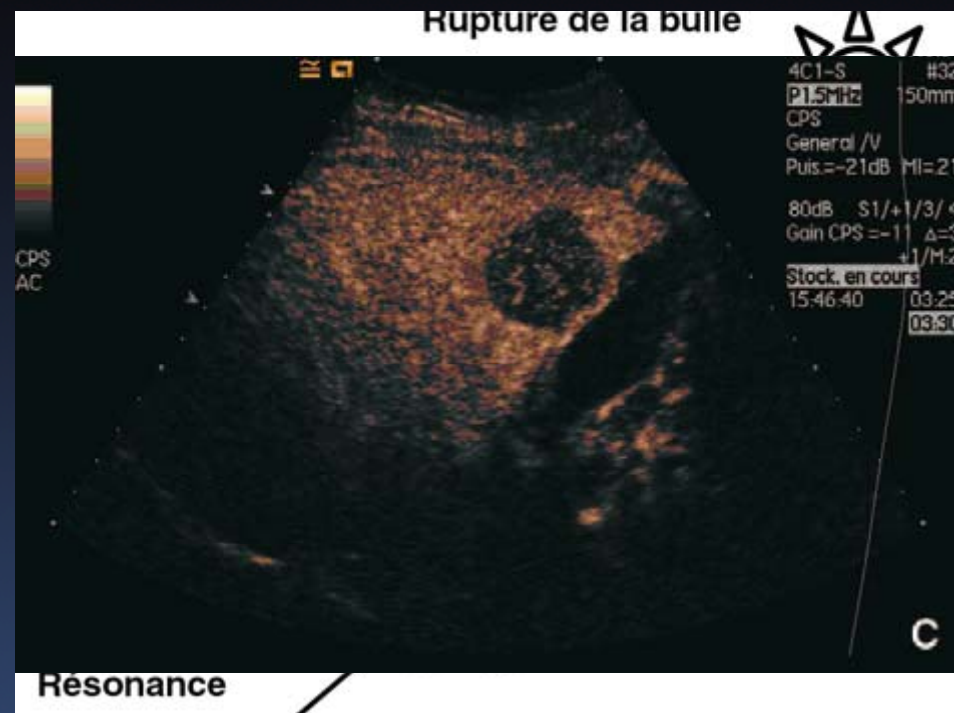
TDM volumique



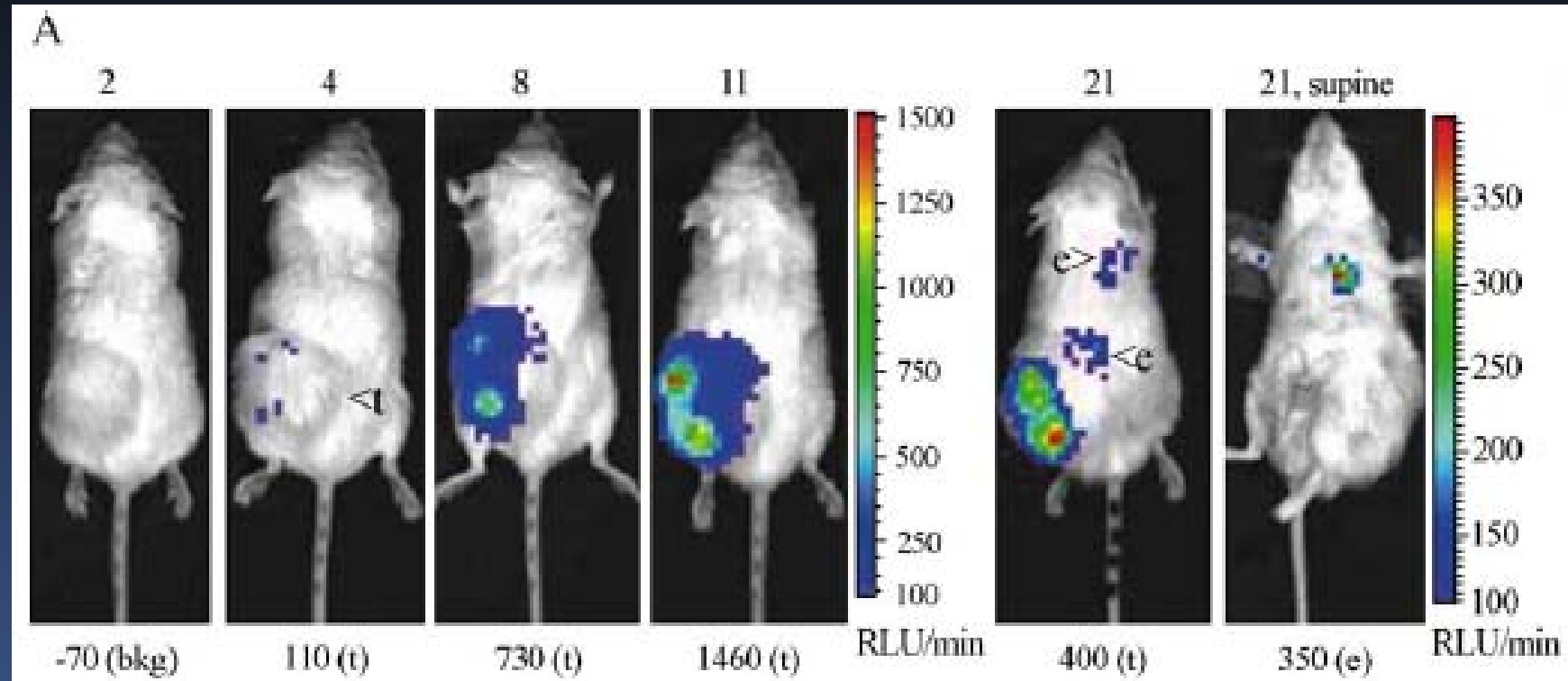
Elastographie



Produits de contraste



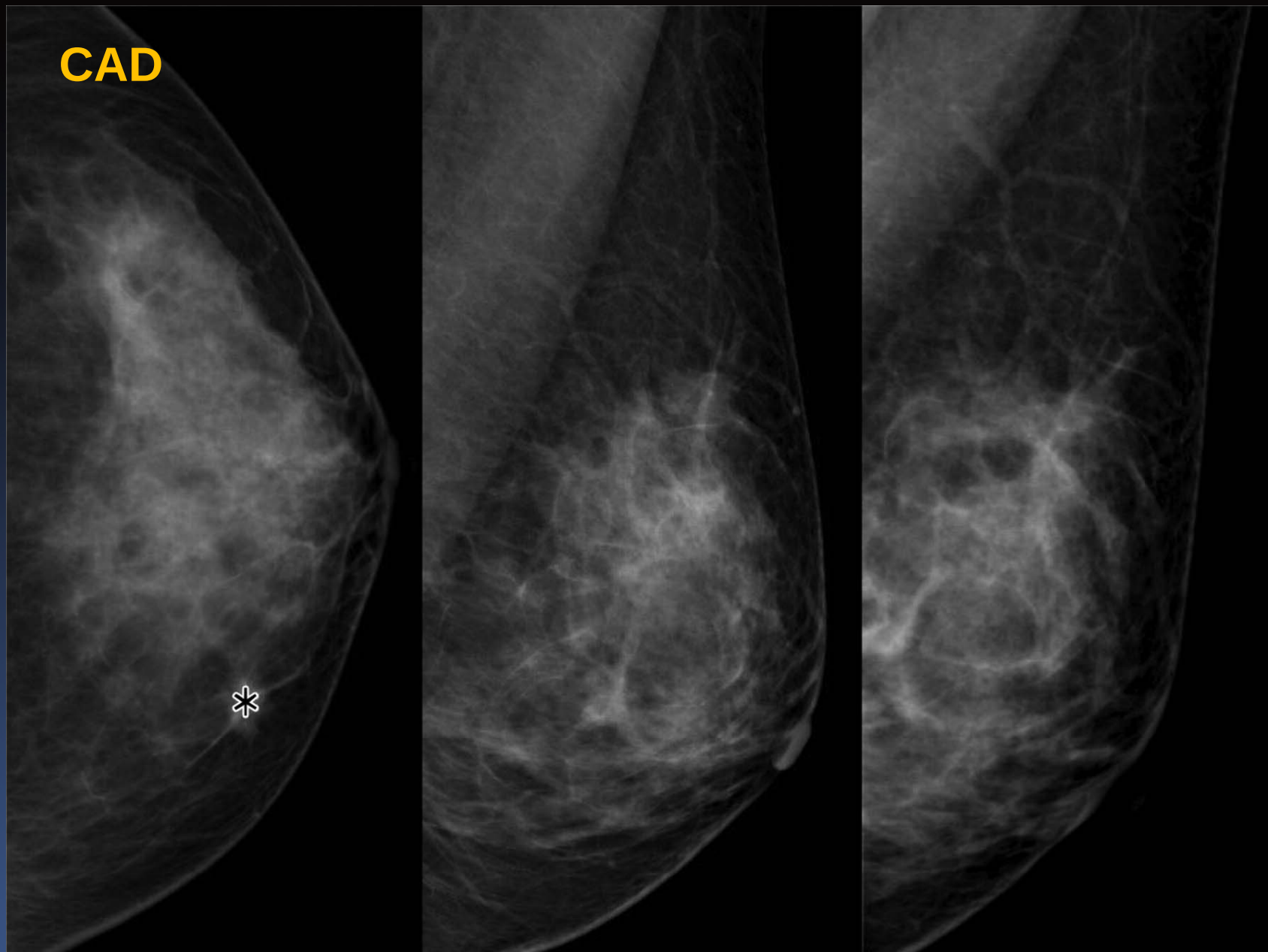
Imagerie moléculaire



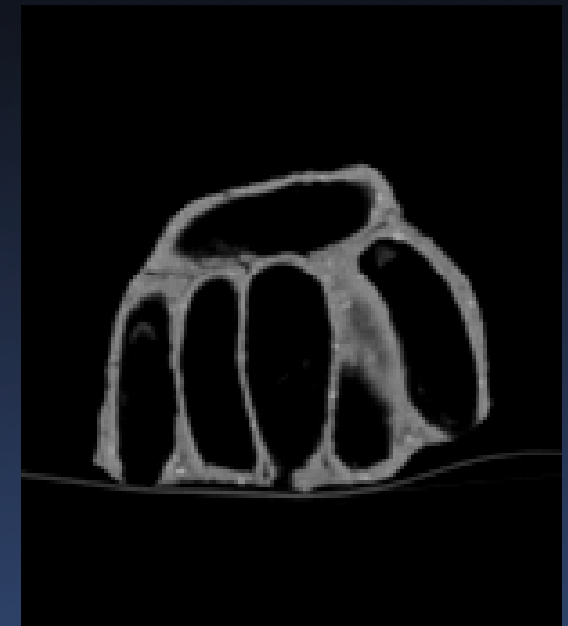
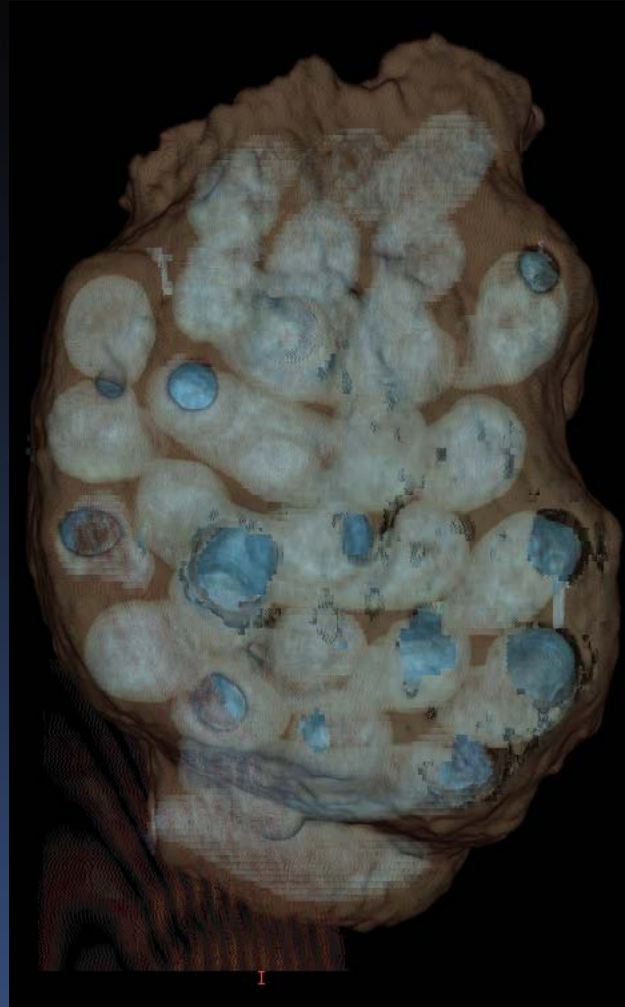
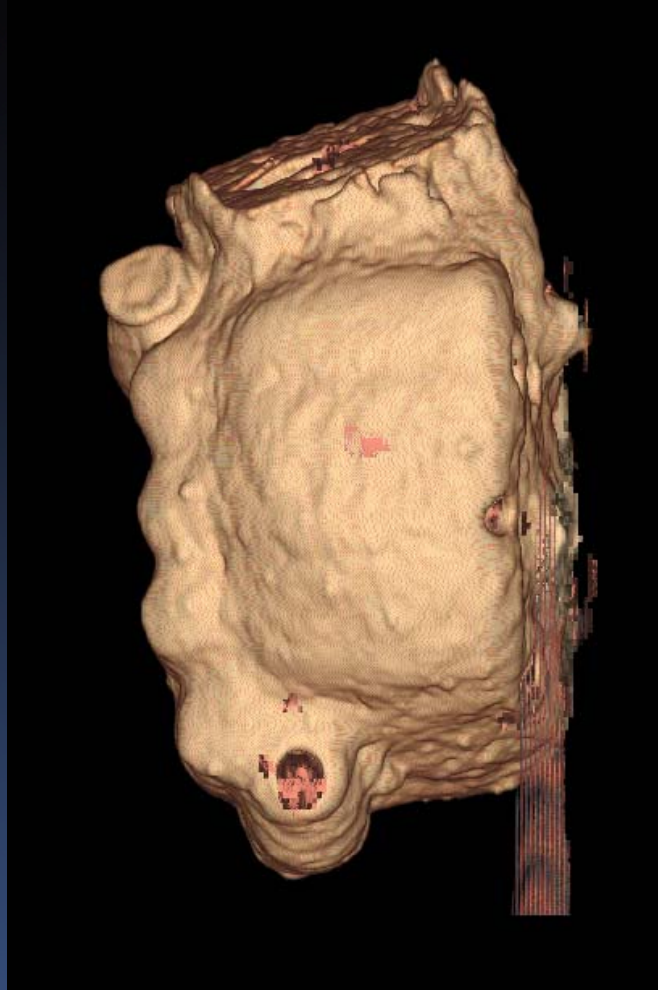
Références

- Reconstruction 3D : Fovia, Volume Graphics
- CAD : Median
- Egyptologie : Dr Samuel Merigeaud, IMA Solutions
- Artistique : Nick Veasey, Leslie Wright

CAD



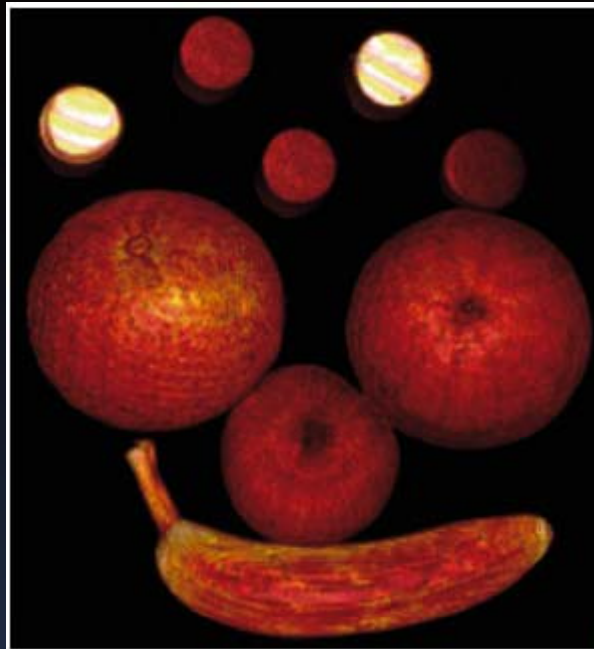
Animaux



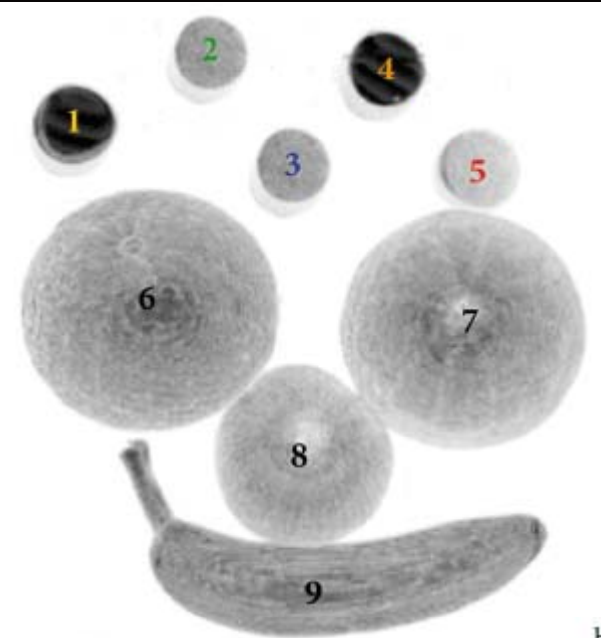
Fruits



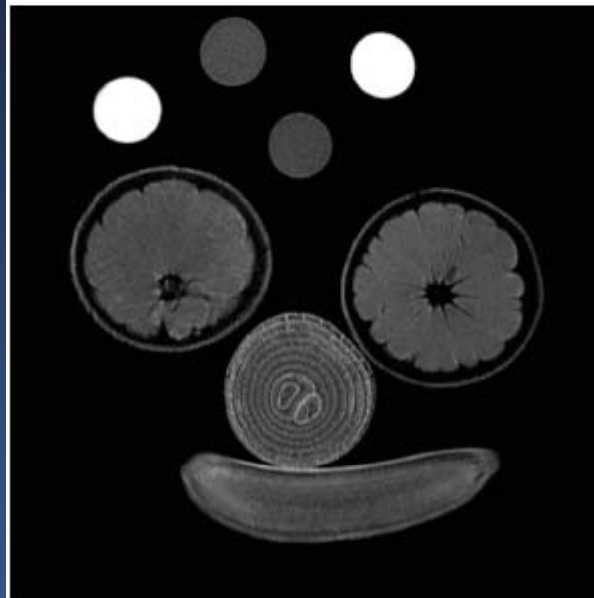
Fruits



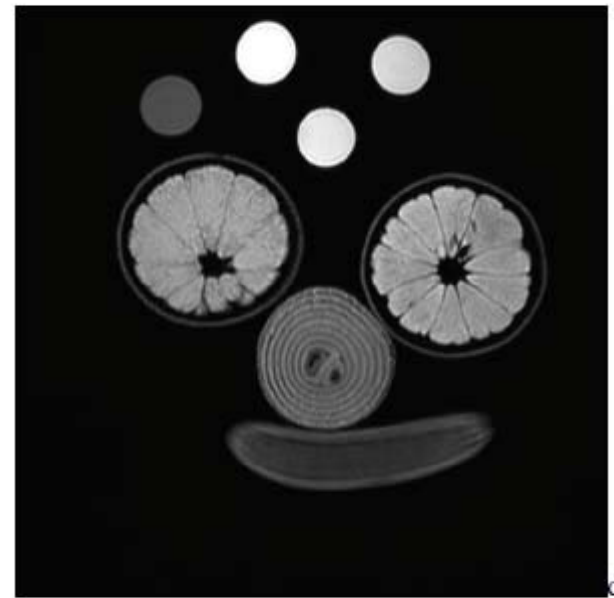
a



b



c



d

Géologie

3D
Ex: 14833
Se: 2
Volume Rendering No cut

DFOV 23.8cm
BONE+/-

R
1
1
9

No VOI
kv 140
mA 305
Rot 1.00s/HE+ 10.6mm/rot
0.6mm 0.531:1/0.2sp
Tilt: 0.0
02:17:07 PM
W = 4095 L = 2048

S 114

CHU GUI DE CHAULIAC MONTPELLIER
RECHERCHE
1409200:
Sep 14 200:cut

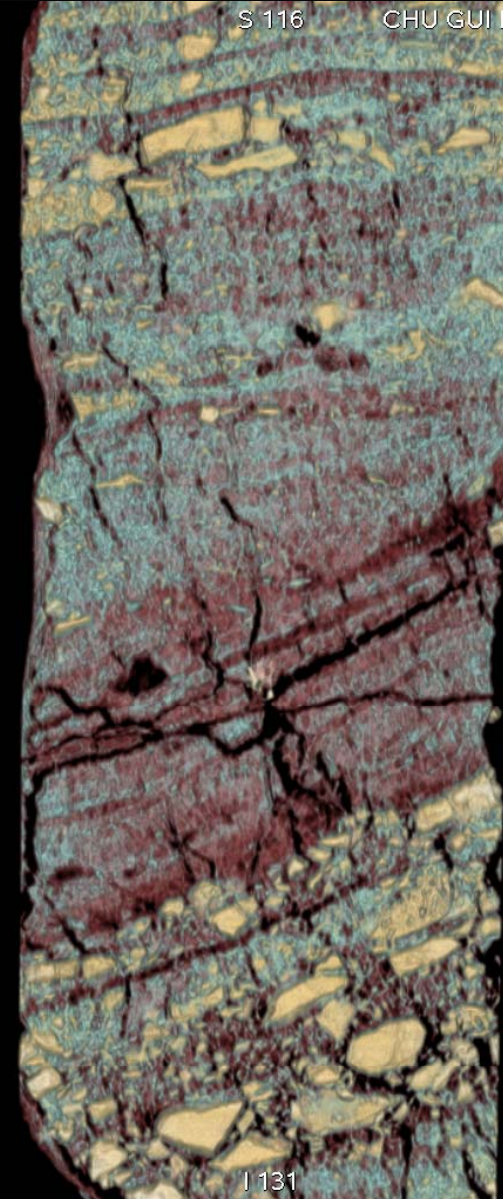


I 124

S 116

CHU GUI DE CHAU

1/rot



I 131

Conclusion

Imagerie in vivo, 2D / 3D / 4D

Etude de la structure interne

Techniques complémentaires : US / RX / RMN

Numérique

Voies de recherche : acquisition / traitement /
interprétation...