





## Cancer du poumon

# Objectifs

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- Identifier de nouveaux biomarqueurs pronostiques et/ou prédictifs chez les patients atteints d'un cancer pulmonaire en imagerie TEP et TDM
- Combiner des informations radiomiques, cliniques et/ou biologiques pour développer des modèles applicables en clinique

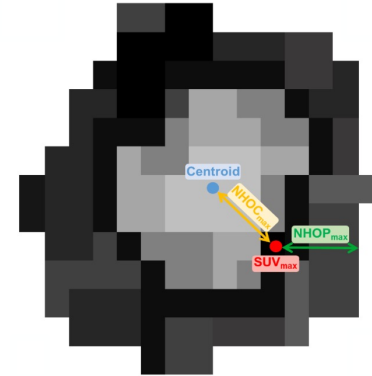
# Originalités

- Accès aux bases de données de l'Institut Curie/Institut du Thorax Curie-Montsouris : nouvelles thérapies, suivi des patients, multimodalités...
- Stratégie de diffusion de biomarqueurs/modèles développés 
- Validation de biomarqueurs/modèles existants 

# Illustration n°1 : nouveaux biomarqueurs en TEP – Narinée



Evaluer des nouveaux biomarqueurs en imagerie TEP



[Proc Natl Acad Sci U S A. 2021 Feb 9;118\(6\):e2018110118. doi: 10.1073/pnas.2018110118.](#)

**Evolutionary dynamics at the tumor edge reveal metabolic imaging biomarkers**

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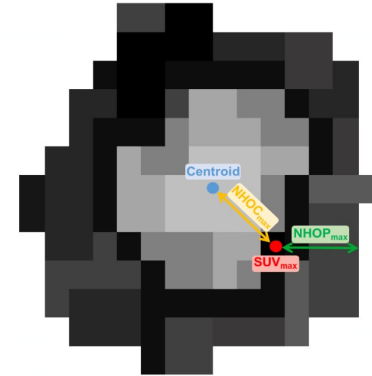
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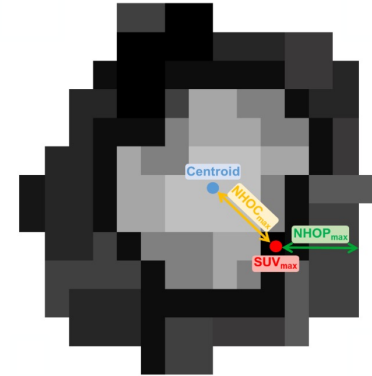
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**Images TEP au 18F-FDG pré-traitement**, CPNPC

Cohorte 1 : 99 → étude technique

Cohorte 2 : 244 → analyse de survie

Données de suivi – **Institut Curie**



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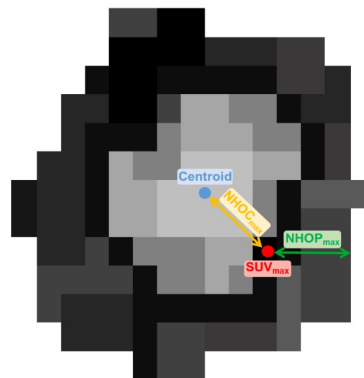
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	HighGrayZoneEmph	SUVmin	SUVmean	SUVmax	SUVpeak	NHOPmax	NHOPpeak	JointEntropyLog10	MTV	TLG	LowGrayZoneEmph	IncDiffMoment	ShortRunEmph	LongRunEmph	Sphericity	NHOCmax	NHOCpeak
HighGrayZoneEmph	1.00	0.41	0.33	0.35	0.30	0.28	0.11	0.29	0.11	0.23	0.32	0.34	0.36	0.11	0.24	0.11	
SUVmin	0.41	1.00	0.72	0.55	0.55	0.30	0.15	0.28	0.11	0.23	0.32	0.34	0.36	0.11	0.24	0.11	
SUVmean	0.41	0.72	1.00	0.94	0.94	0.33	0.19	0.32	0.11	0.23	0.32	0.34	0.36	0.11	0.24	0.11	
SUVmax	0.33	0.55	0.94	1.00	0.99	0.19	0.26	0.17	0.19	0.47	0.33	0.27	0.25	0.22	0.20	0.34	
SUVpeak	0.35	0.55	0.94	0.99	1.00	0.19	0.21	0.25	0.25	0.52	0.36	0.31	0.29	0.27	0.20	0.32	
NHOPmax	0.28	0.30	0.33	0.35	0.30	1.00	0.50	0.22	0.28	0.29	0.30	0.25	0.25	0.24	0.21	0.43	
NHOPpeak	0.11	0.15	0.19	0.26	0.21	0.50	1.00	0.11	0.11	0.20	0.27	0.19	0.12	0.12	0.22	0.45	
JointEntropyLog10	0.29	0.11	0.11	0.11	0.11	0.22	0.11	1.00	0.92	0.85	0.63	0.68	0.70	0.73	0.41	0.30	
MTV	0.11	0.28	0.11	0.19	0.25	0.28	0.11	0.92	1.00	0.94	0.72	0.83	0.82	0.84	0.48	0.38	
TLG	0.23	0.31	0.47	0.52	0.26	0.29	0.85	0.94	1.00	0.74	0.79	0.78	0.79	0.51	0.43	0.60	
LowGrayZoneEmph	0.29	0.32	0.30	0.33	0.36	0.30	0.27	0.63	0.72	0.74	1.00	0.73	0.69	0.69	0.40	0.53	
IncDiffMoment	0.32	0.32	0.32	0.27	0.31	0.25	0.19	0.68	0.83	0.79	0.73	1.00	0.94	0.94	0.40	0.59	
ShortRunEmph	0.34	0.36	0.36	0.29	0.29	0.29	0.12	0.70	0.82	0.78	0.69	0.94	1.00	0.99	0.25	0.43	
LongRunEmph	0.36	0.36	0.36	0.22	0.27	0.28	0.12	0.73	0.84	0.79	0.69	0.94	0.99	1.00	0.25	0.50	
Sphericity	0.24	0.11	0.11	0.29	0.20	0.21	0.22	0.41	0.48	0.51	0.40	0.40	0.25	0.26	1.00	0.60	
NHOCmax	0.11	0.24	0.34	0.32	0.43	0.45	0.30	0.38	0.43	0.40	0.42	0.32	0.33	0.40	0.40	1.00	
NHOCpeak	0.11	0.11	0.21	0.35	0.34	0.35	0.39	0.49	0.57	0.60	0.53	0.59	0.49	0.50	0.60	0.70	1.00



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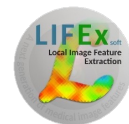
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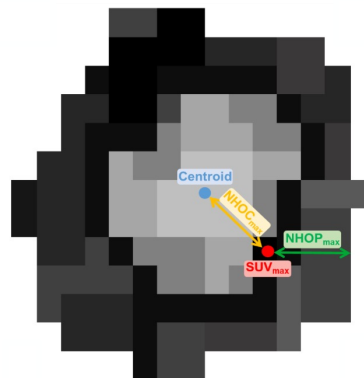
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Données de suivi – **Institut Curie**



	HighGrayZoneEmph	SUVmin	SUVmean	SUVmax	SUVpeak	NHOPmax	NHOPpeak	JointEntropyLog10	MTV	TLG	LowGrayZoneEmph	InvDiffMoment	ShortRunEmph	LongRunEmph	Sphericity	NHOCmax	NHOCpeak
HighGrayZoneEmph	1.00	0.41	0.33	0.35	0.35	0.35	0.35	0.11	0.29	0.11	0.24	0.32	0.34	0.36	0.24	0.32	0.34
SUVmin	0.41	1.00	0.72	0.55	0.55	0.55	0.55	0.15	0.28	0.23	0.32	0.34	0.36	0.36	0.24	0.32	0.34
SUVmean	0.41	0.72	1.00	0.94	0.94	0.94	0.94	0.15	0.28	0.23	0.32	0.34	0.36	0.36	0.24	0.32	0.34
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SUVpeak	0.35	0.55	0.94	0.99	1.00	1.00	1.00	0.15	0.28	0.23	0.32	0.34	0.36	0.36	0.24	0.32	0.34
NHOPmax	0.35	0.55	0.94	0.99	0.99	1.00	1.00	0.15	0.28	0.23	0.32	0.34	0.36	0.36	0.24	0.32	0.34
NHOPpeak	0.35	0.55	0.94	0.99	0.99	1.00	1.00	0.15	0.28	0.23	0.32	0.34	0.36	0.36	0.24	0.32	0.34
JointEntropyLog10	0.11	0.15	0.15	0.15	0.15	0.15	0.15	1.00	0.92	0.85	0.63	0.68	0.70	0.73	0.41	0.38	0.40
MTV	0.11	0.15	0.15	0.15	0.15	0.15	0.15	0.92	1.00	0.94	0.72	0.83	0.82	0.84	0.48	0.38	0.40
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LowGrayZoneEmph	0.29	0.28	0.26	0.33	0.36	0.38	0.37	0.63	0.72	0.74	1.00	0.73	0.69	0.69	0.40	0.40	0.53
InvDiffMoment	0.32	0.32	0.26	0.27	0.31	0.25	0.19	0.68	0.83	0.79	0.73	1.00	0.94	0.94	0.40	0.42	0.59
ShortRunEmph	0.34	0.32	0.25	0.29	0.29	0.29	0.19	0.70	0.82	0.78	0.69	0.94	1.00	0.99	0.25	0.32	0.49
LongRunEmph	0.36	0.36	0.22	0.27	0.28	0.19	0.19	0.73	0.84	0.79	0.69	0.94	0.99	1.00	0.25	0.33	0.50
Sphericity	0.24	0.15	0.15	0.29	0.29	0.21	0.22	0.41	0.48	0.51	0.40	0.40	0.25	0.25	1.00	0.40	0.60
NHOCmax	0.32	0.24	0.34	0.32	0.43	0.45	0.30	0.38	0.43	0.40	0.42	0.32	0.33	0.40	0.40	1.00	0.70
NHOCpeak	0.32	0.12	0.21	0.35	0.34	0.35	0.39	0.49	0.57	0.60	0.53	0.59	0.49	0.50	0.60	0.70	1.00

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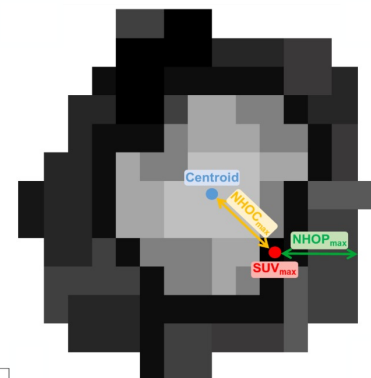
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HighGrayZoneEmph	1.00	0.41	0.33	0.35	0.35	0.11	0.11	0.11	0.11	0.11	0.29	0.11	0.11	0.11	0.24		
SUVmin	0.41	1.00	0.72	0.55	0.55	0.10	0.10	0.15	0.28	0.15	0.23	0.32	0.34	0.36		0.11	
SUVmean	0.41	0.72	1.00	0.94	0.94	0.10	0.10	0.15	0.28	0.15	0.23	0.32	0.34	0.36		0.11	
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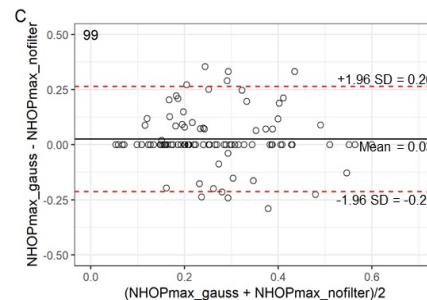
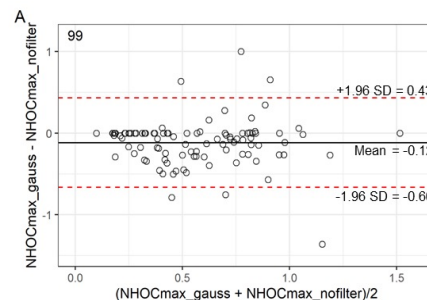
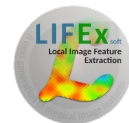
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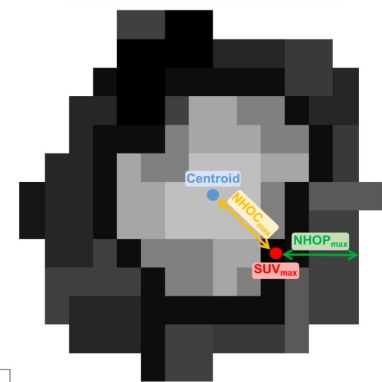
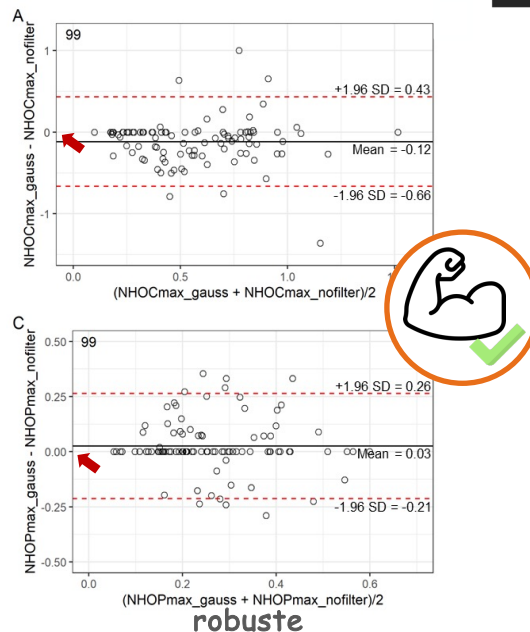
Cohorte 2 : 244 → analyse de survie

Données de suivi – **Institut Curie**



	HighGrayZoneEmph	SUVmin	SUVmean	SUVmax	SUVpeak	NHOCmax	NHOCpeak	JointEntropyLog10	MTV	TLG	LowGrayZoneEmph	ImDiffMoment	ShortRunEmph	LongRunEmph	Sphericity	NHOCmax	NHOCpeak
HighGrayZoneEmph	1.00	0.41	0.33	0.35	0.35	0.11	0.11	0.11	0.11	0.11	0.29	0.11	0.11	0.11	0.24		
SUVmin	0.41	1.00	0.72	0.55	0.55	0.10	0.10	0.15	0.28	0.15	0.23	0.32	0.34	0.36		0.11	0.11
SUVmean	0.41	0.72	1.00	0.94	0.94	0.10	0.10	0.15	0.28	0.15	0.23	0.32	0.34	0.36		0.11	0.11
SUVmax	0.33	0.55	0.94	1.00	0.99	0.10	0.10	0.15	0.28	0.15	0.23	0.32	0.34	0.36		0.11	0.11
SUVpeak	0.35	0.55	0.94	0.99	1.00	0.10	0.10	0.15	0.28	0.15	0.23	0.32	0.34	0.36		0.11	0.11
NHOCmax	0.11	0.10	0.10	0.10	0.10	1.00	0.50	0.22	0.28	0.25	0.25	0.36	0.31	0.29	0.20	0.32	0.34
NHOCpeak	0.11	0.10	0.10	0.10	0.10	0.50	1.00	0.22	0.28	0.25	0.25	0.36	0.31	0.29	0.20	0.32	0.34
JointEntropyLog10	0.11	0.10	0.10	0.10	0.10	0.22	0.22	1.00	0.92	0.85	0.63	0.68	0.70	0.73	0.41	0.38	0.38
MTV	0.11	0.28	0.15	0.15	0.15	0.28	0.28	0.92	1.00	0.94	0.72	0.83	0.82	0.84	0.48	0.38	0.38
TLG	0.11	0.28	0.15	0.15	0.15	0.28	0.28	0.94	0.94	1.00	0.74	0.79	0.78	0.79	0.51	0.43	0.43
LowGrayZoneEmph	0.29	0.23	0.20	0.23	0.23	0.25	0.25	0.63	0.72	0.74	1.00	0.73	0.69	0.69	0.40	0.40	0.53
ImDiffMoment	0.11	0.32	0.10	0.27	0.31	0.25	0.19	0.68	0.83	0.79	0.73	1.00	0.94	0.94	0.40	0.42	0.59
ShortRunEmph	0.34	0.34	0.25	0.29	0.29	0.31	0.19	0.70	0.82	0.78	0.69	0.94	1.00	0.99	0.25	0.32	0.49
LongRunEmph	0.36	0.36	0.22	0.27	0.28	0.19	0.19	0.73	0.84	0.79	0.69	0.94	0.99	1.00	0.25	0.33	0.50
Sphericity	0.24	0.15	0.15	0.20	0.20	0.21	0.22	0.41	0.48	0.51	0.40	0.40	0.40	0.40	1.00	0.40	0.60
NHOCmax		0.10	0.10	0.10	0.10	1.00	0.50	0.22	0.28	0.25	0.25	0.36	0.31	0.29	0.20	0.32	0.34
NHOCpeak		0.10	0.10	0.10	0.10	0.50	1.00	0.22	0.28	0.25	0.25	0.36	0.31	0.29	0.20	0.32	0.34

complémentaire



Proc Natl Acad Sci U S A. 2021 Feb 9;118(6):e2018110118. doi: 10.1073/pnas.2018110118.

**Evolutionary dynamics at the tumor edge reveal metabolic imaging biomarkers**

Juan Jiménez-Sánchez <sup>1</sup>, Jesús J Bosque <sup>1</sup>, Germán A Jiménez Londoño <sup>2</sup>, David Molina-García <sup>1</sup>, Álvaro Martínez <sup>1</sup> <sup>3</sup>, Julián Pérez-Beteta <sup>1</sup>, Carmen Ortega-Sabater <sup>1</sup>, Antonio F Hongoero Martínez <sup>4</sup>, Ana M García Vicente <sup>5</sup>, Gabriel F Calvo <sup>6</sup>, Víctor M Pérez-García <sup>5</sup>

Eur Radiol. 2022 Jun;32(6):3889-3902. doi: 10.1007/s00330-021-08523-3. Epub 2022 Feb 8.

**SUVmax to tumor perimeter distance: a robust radiomics prognostic biomarker in resectable non-small cell lung cancer patients**

Germán Andrés Jiménez Londoño <sup>1</sup>, Ana María García Vicente <sup>2</sup>, Jesús J Bosque <sup>3</sup>, Mariano Amo-Salas <sup>4</sup>, Julián Pérez-Beteta <sup>3</sup>, Antonio Francisco Hongoero-Martínez <sup>5</sup>, Víctor M Pérez-García <sup>3</sup>, Anel María Soriano Castreón <sup>2</sup>



# Illustration n°1 : nouveaux biomarqueurs en TEP – Narinée



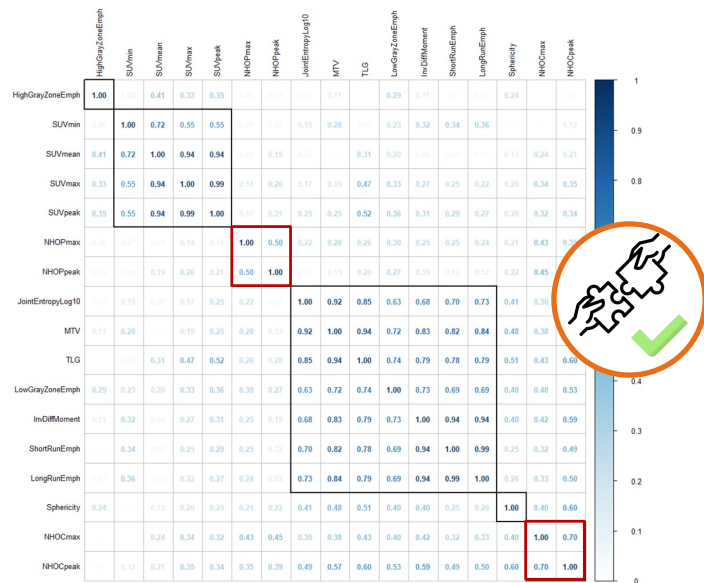
Evaluer des nouveaux biomarqueurs en imagerie TEP

**Images TEP au 18F-FDG pré-traitement**, CPNPC

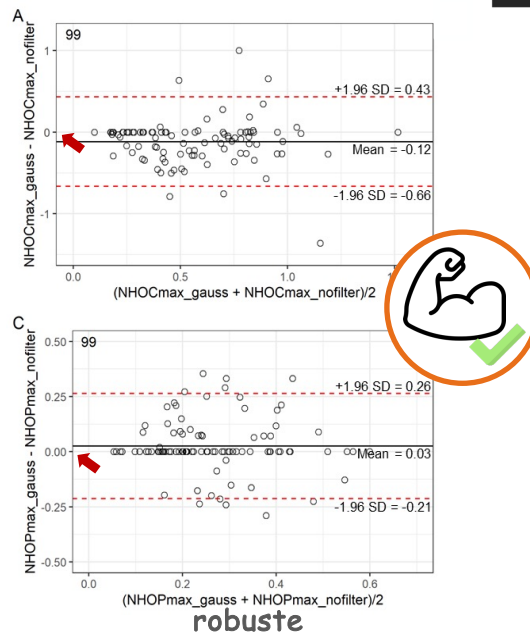
Cohorte 1 : 99 → étude technique

Cohorte 2 : 244 → analyse de survie

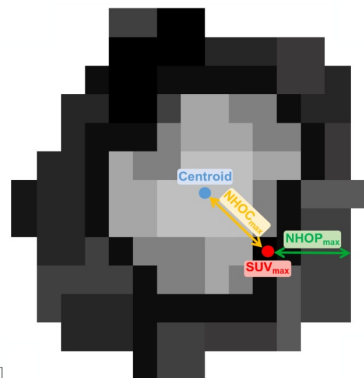
Données de suivi – **Institut Curie**



complémentaire



robuste



Proc Natl Acad Sci U S A. 2021 Feb 9;118(6):e2018110118. doi: 10.1073/pnas.2018110118.

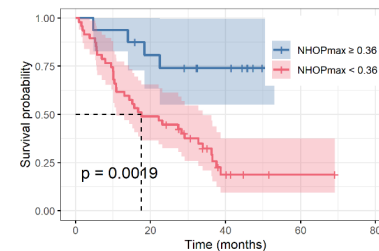
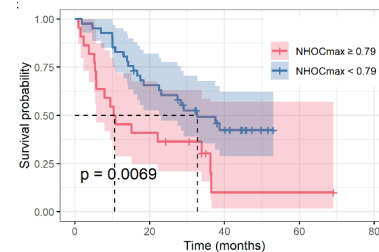
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Juan Jiménez-Sánchez <sup>1</sup>, Jesús J Bosque <sup>1</sup>, Germán A Jiménez-Londoño <sup>2</sup>, David Molina-García <sup>1</sup>, Álvaro Martínez <sup>1</sup>, Julián Pérez-Beteta <sup>1</sup>, Carmen Ortega-Sabater <sup>1</sup>, Antonio F Hongo-Martínez <sup>2</sup>, Ana M García Vicente <sup>2</sup>, Gabriel F Calvo <sup>3</sup>, Víctor M Pérez-García <sup>3</sup>

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Germán Andrés Jiménez-Londoño <sup>1</sup>, Ana María García Vicente <sup>2</sup>, Jesús J Bosque <sup>3</sup>, Mariano Amo-Salas <sup>4</sup>, Julián Pérez-Beteta <sup>3</sup>, Antonio Francisco Hongo-Martínez <sup>5</sup>, Víctor M Pérez-García <sup>3</sup>, Anel María Soriano Castreón <sup>2</sup>



# Illustration n°1 : nouveaux biomarqueurs en TEP – Narinée



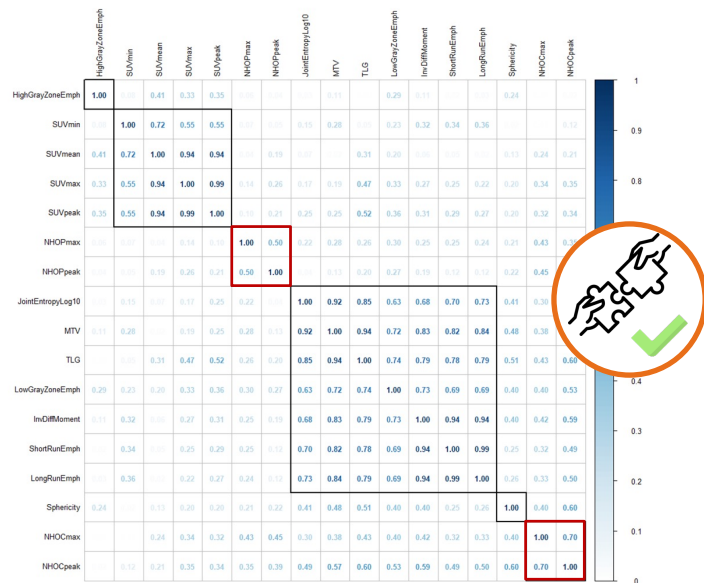
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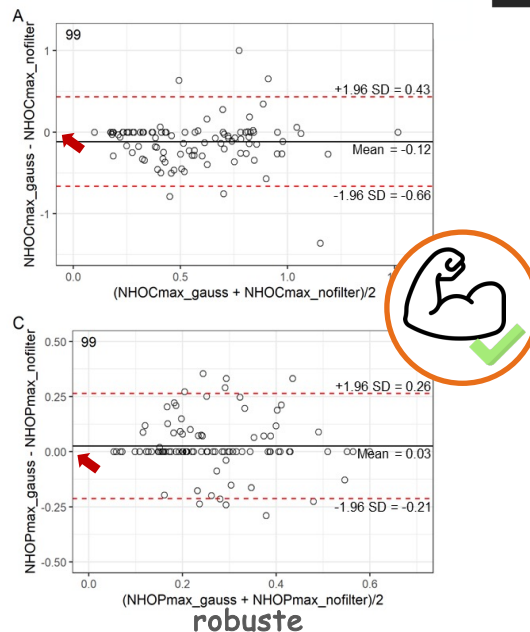
Cohorte 1 : 99 → étude technique

Cohorte 2 : 244 → analyse de survie

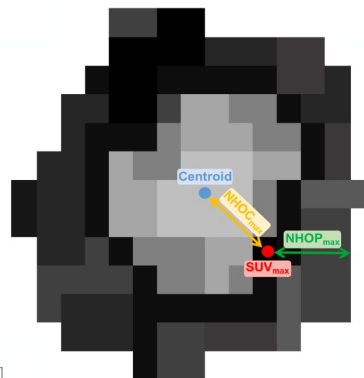
Données de suivi – **Institut Curie**



complémentaire



robuste



Proc Natl Acad Sci U S A. 2021 Feb 9;118(6):e2018110118. doi: 10.1073/pnas.2018110118.

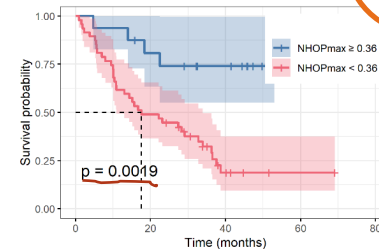
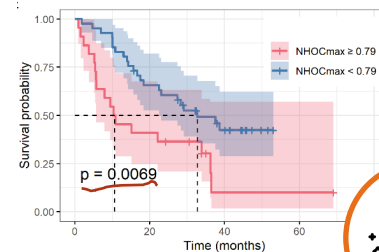
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pronostique

# Illustration n°2 : développer et valider un modèle – Hornella



Prédiction de la réponse aux inhibiteurs de tyrosine Kinase (TKI) chez des patients atteints de cancer broncho-pulmonaire avec mutation EGFR

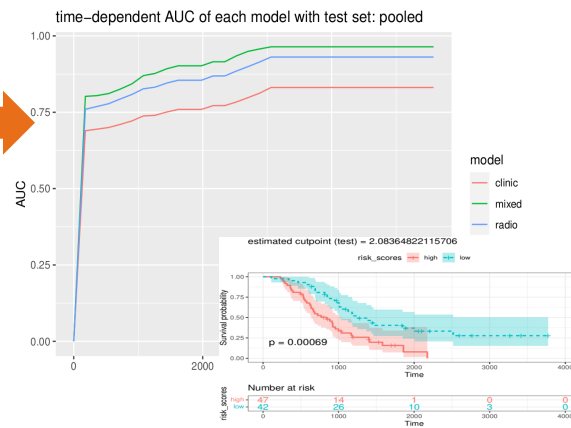
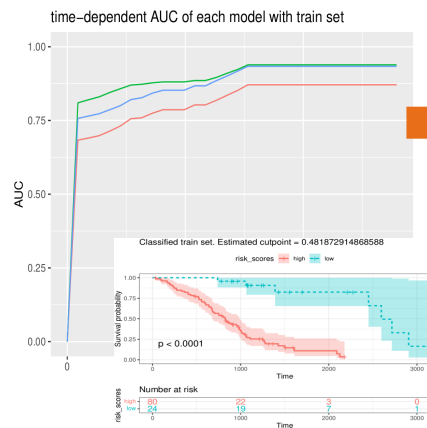


Données cliniques, **radiologiques (TDM)** et **d'imagerie métabolique (FDG-TEP)** & données SNDS

Set d'entraînement : 104 patients (Institut Curie)

Set de test : 89 patients (Caen, Clermont, Dijon, Lille, Marseille, Montpellier)

Characteristic	HR	95% CI	p-value
age	1.04	1.02, 1.07	<b>0.001</b>
localisation_muta_EGFR_E19			
0			
1	0.37	0.21, 0.63	<b>&lt;0.001</b>
cerveau			
0			
1	1.64	0.97, 2.76	<b>0.065</b>
META_FOIE			
high			
low	0.45	0.19, 1.05	<b>0.066</b>
SUVmeanFoie			
high			
low	2.41	1.20, 4.81	<b>0.013</b>
SUVrate_foie			
high			
low	3.20	1.41, 7.27	<b>0.005</b>
SUVmax_PrimPul			
high			
low	0.40	0.23, 0.72	<b>0.002</b>
NHOCmax_PrimPul			
high			
low	1.86	1.01, 3.45	<b>0.048</b>
SPDmax_PrimPul			
high			
low	5.28	2.60, 10.7	<b>&lt;0.001</b>
Sphericity_PrimPul			
high			
low	0.64	0.35, 1.17	0.15
sdNHOCmax			
high			
low	0.48	0.22, 1.04	<b>0.064</b>



**Precision  
Predict**

2020-2024

PI : Nicolas Girard

**bpi**france

**HD** HEALTH  
DATA HUB

# Illustration n°3 : 1+1 > 2 – Nicolas

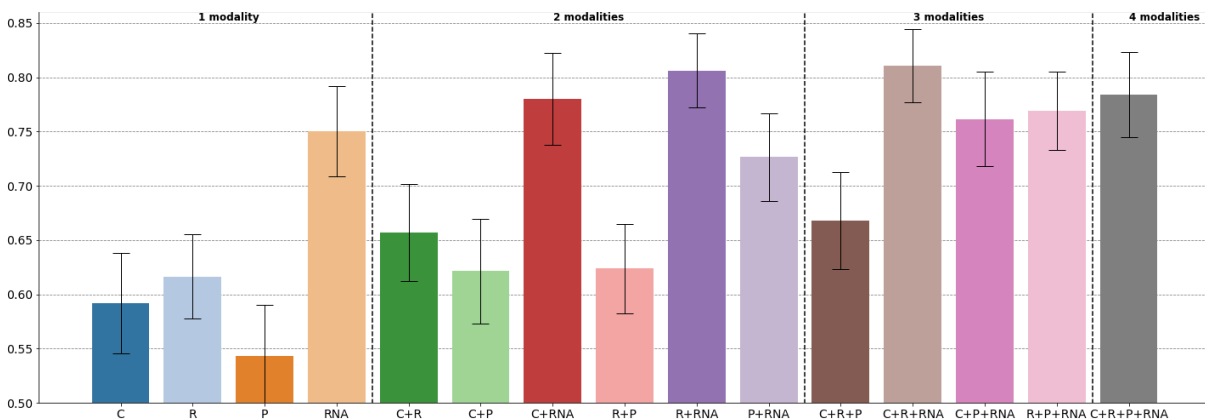


Prédiction de la réponse à l'immunothérapie

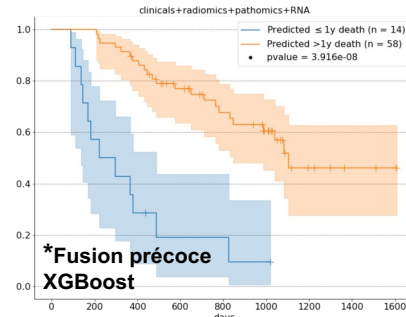
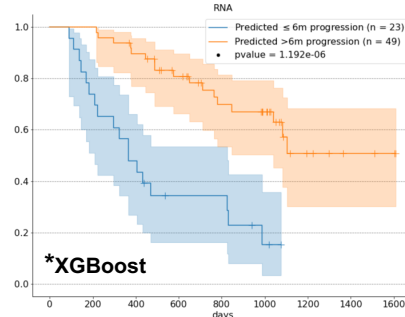
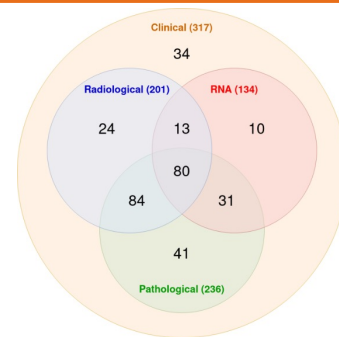


Données cliniques, pathologiques, génomiques et radiomiques (TEP-FDG)  
**317 patients** avec CPNPC traité par immunothérapie (Institut Curie)

Survie globale à 1 an (AUC) – Fusion tardive de modèles XGBoost



C : Clinique  
R : Radiomique  
P : Pathomique  
RNA : Génomique



**TIPIT**  
2020-2024  
PI : Emmanuel Barillot

Fondation pour la recherche sur le cancer



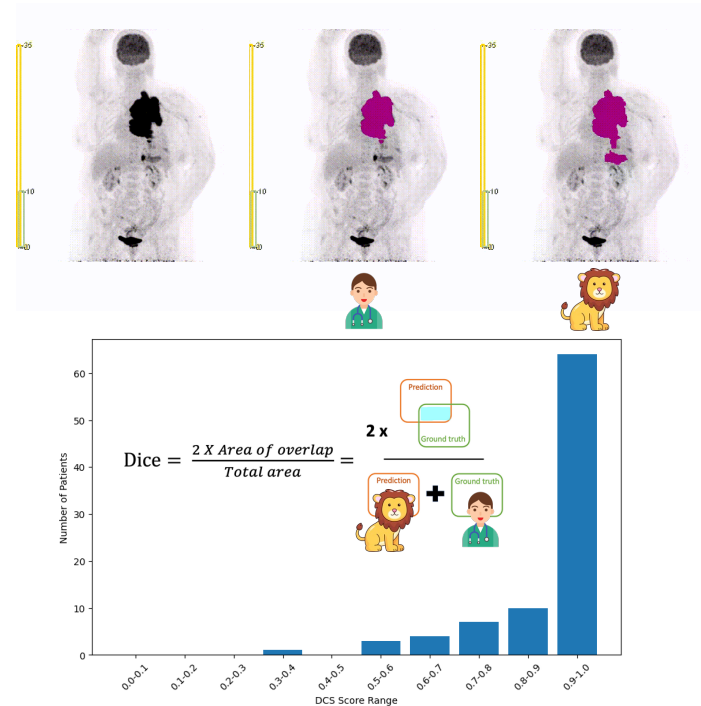


# Illustration n°4 : évaluation de LION – Mathilde

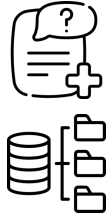


Evaluation d'une segmentation automatique des lésions tumorales

**93 patients** avec un CPNPC avancé (Institut Curie)  
Segmentation de référence : expert + seuillage > 4 SUV



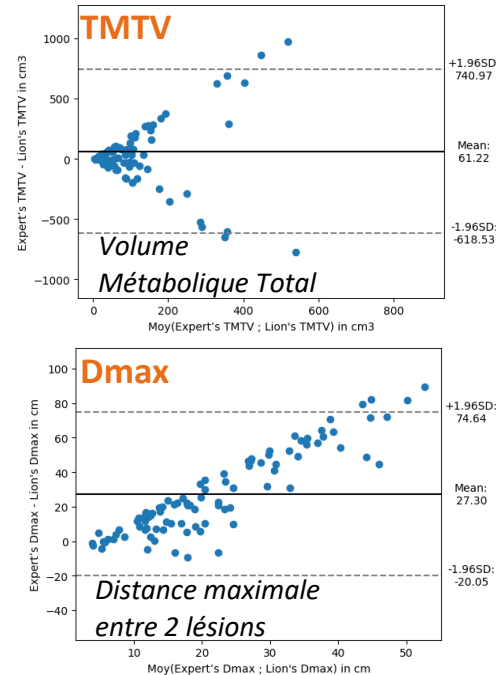
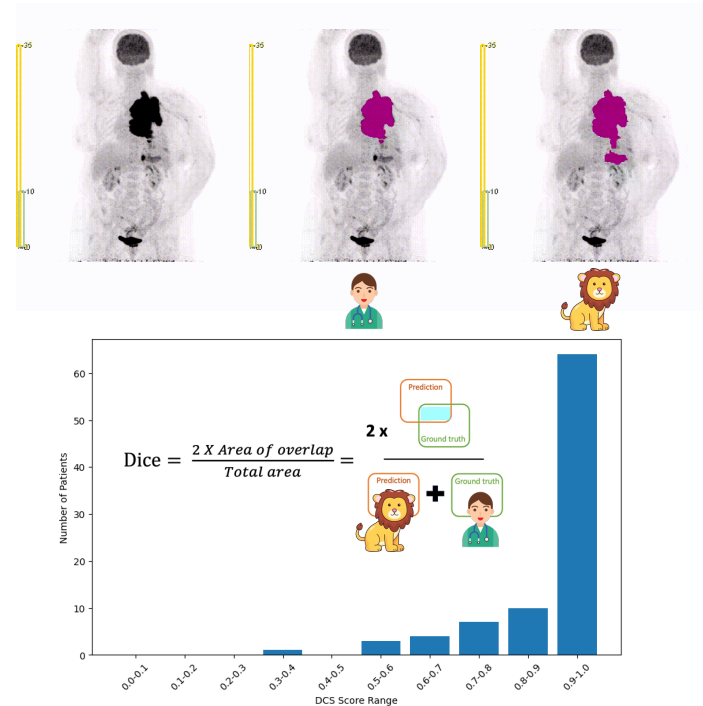
# Illustration n°4 : évaluation de LION – Mathilde



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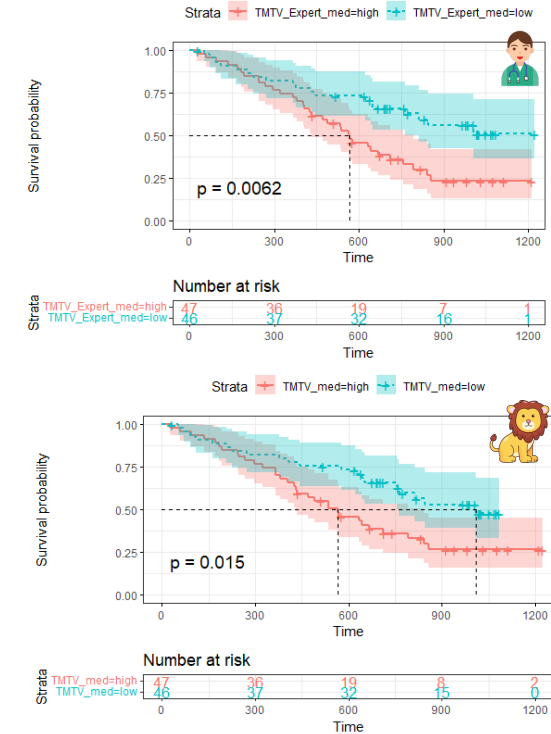
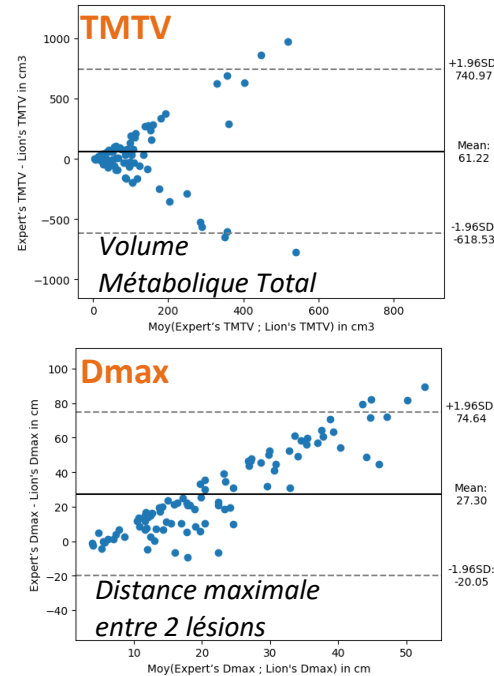
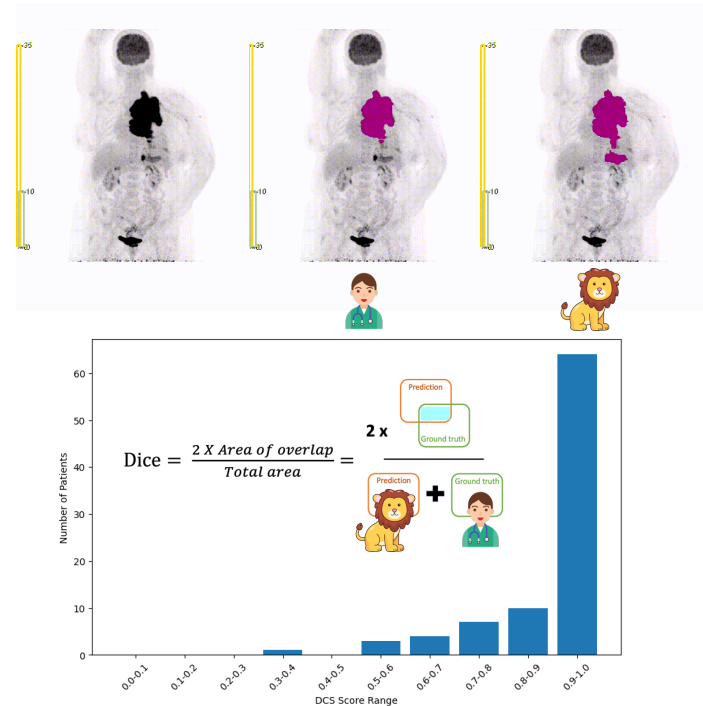
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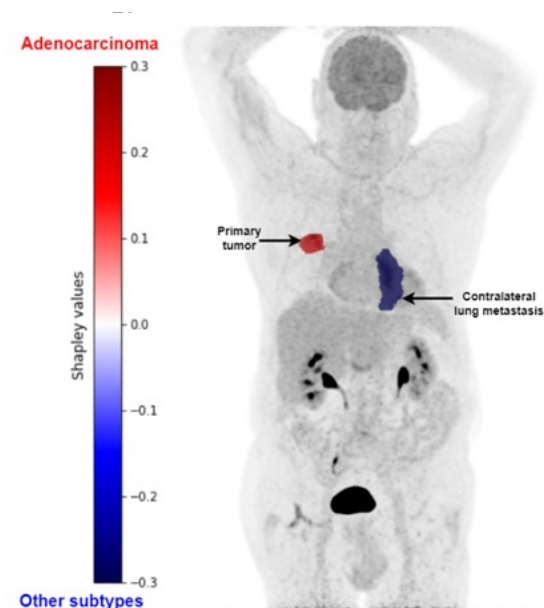
Segmentation de référence : expert + seuillage > 4 SUV



# Autres illustrations



- Prédiction de la réponse à l'immunothérapie chez des patients atteints de cancer du poumon non à petites cellules à partir d'images TEP (Julie)
- Shap-MAP appliquées au cancer du poumon (Nicolas)



Influence de chaque lésion sur la prédiction du sous-type de CPNC

# Perspectives envisagées sur lesquelles cogiter

- Utiliser les données des essais cliniques déjà collectées ?
- LIFEx : plateforme de diffusion de nos nouveaux biomarqueurs/modèles
- Collaboration avec d'autres centres pour la validation externe :
  - Centre Antoine Lacassagne, Nice
  - Institut Jules Bordet, Bruxelles
  - Autres ? Thèses de médecine ?
- Prédire la survenue des toxicités des traitements ?
- Outil de calcul d'un score utilisable en RCP ?

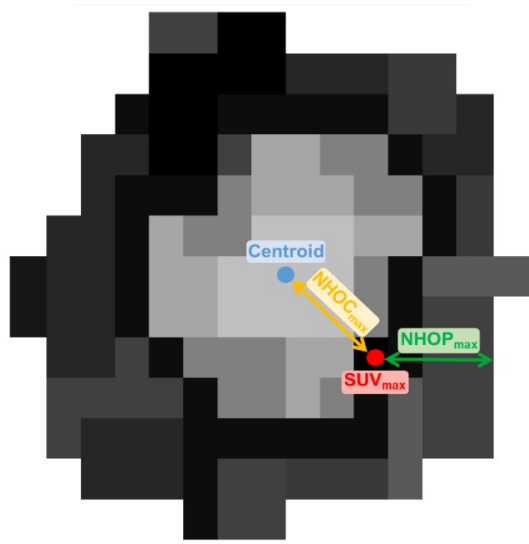
The screenshot displays the 'NSCLC Pro Score' application window. It features a yellow background with a green play button icon in the top right corner. The interface is organized into several sections: 'Patient informations' with fields for Age (64), Size (168.0 cm), and Weight (95.0 kg); '(all) ROI informations' with fields for TMTV (295.077), DMaxVox (21.861 cm), sDMaxVox (1.038e+0 cm/kg/cm), and SDSphericity (0.0793); and 'Organ informations' with fields for Spleen/Liver (SUV/SUV) (0.7626) and TMTV\_Pleura (0 cm3). At the bottom, there is a 'Run' button and a status bar indicating 'LinearPredictor=-1.963 (with p=0.140)' and 'NSCLCproscore: Low score'.

Section	Field	Value
Patient informations	Age [Y]	64
	Size [cm]	168.0
	Weight [Kg]	95.0
(all) ROI informations	TMTV [cm3]	295.077
	DMaxVox [cm]	21.861
	sDMaxVox [cm/kg/cm]	1.038e+0
	SDSphericity	0.0793
Organ informations	Spleen/Liver [SUV/SUV]	0.7626
	TMTV_Pleura [cm3]	0

Run

LinearPredictor=-1.963 (with p=0.140)  
NSCLCproscore: Low score





$$\text{NHOC} = \frac{D [P_{\text{suv}} - P_c]}{R}$$

$$\text{NHOP} = \frac{D_{\min} [P_{\text{suv}} - P_p]}{R}$$

$V_{\text{sphère}} = V_{\text{tumeur}}$

