



# Innovations en Imagerie Médicale

## ARIANES Hauts-de-France

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# DEMOGRAPHIE MONDIALE

## La population mondiale en 2050 et au-delà

### Les 5 pays les plus peuplés

En 2015

**Chine**  
1,38 Md

**Inde**  
1,31 Md

**États-Unis**  
321,8 M

**Indonésie**  
257,6 M

**Brésil**  
207,8 M

**France**  
64,4 M

**UE à 28**  
505,2 M

En 2050

**Inde**  
1,71 Md

**Chine**  
1,35 Md

**Nigeria**  
398,5 M

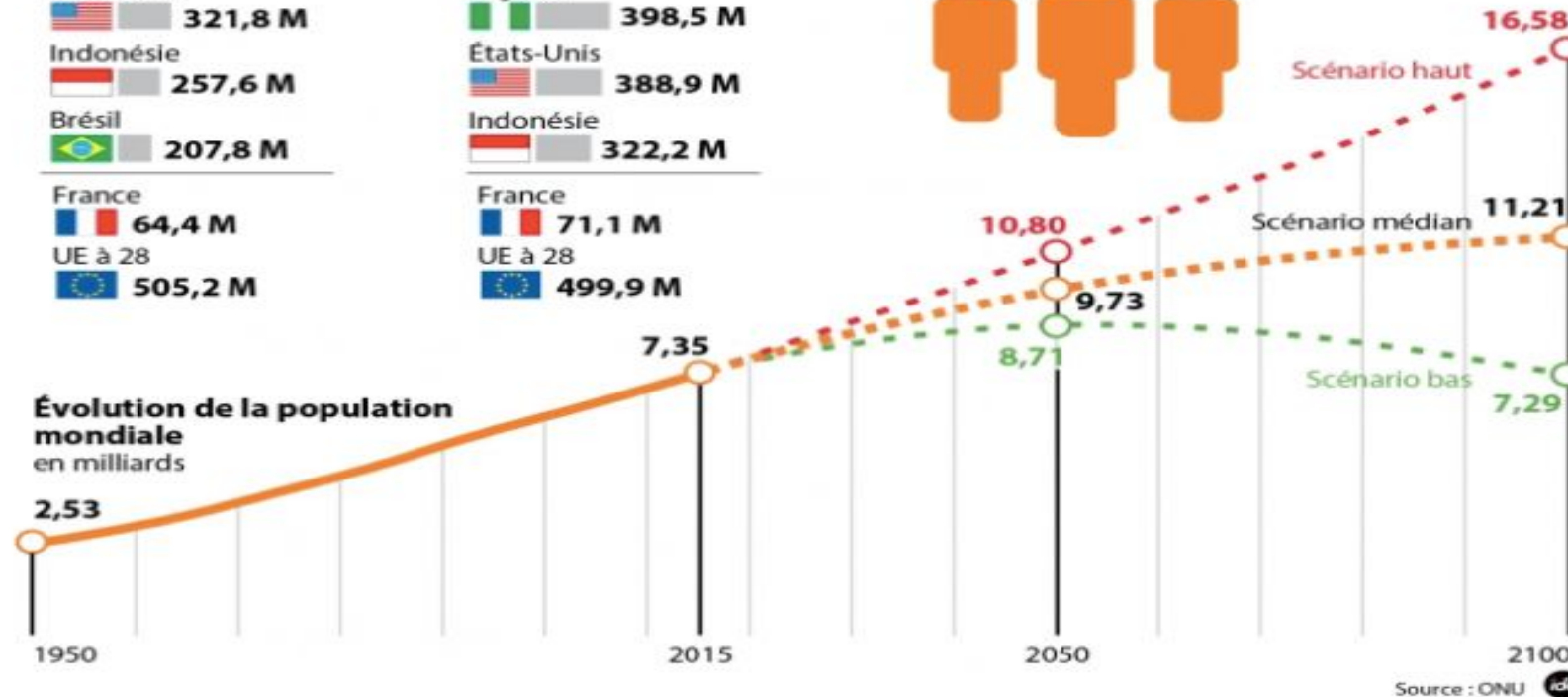
**États-Unis**  
388,9 M

**Indonésie**  
322,2 M

**France**  
71,1 M

**UE à 28**  
499,9 M

**9,7 milliards d'humains en 2050**



↗ de la population mondiale 9,7 milliards en 2050 vs 7,6 en 2017

Source : ONU 2015

Malgré une ↘ de la croissance démographique  
+ 33% sur les 30 prochaines années vs + 45% sur les 30 précédentes

# Leading causes 2016 → 2040

- Ischaemic heart disease
- Stroke
- Lower respiratory infections
- Diarrhoeal diseases
- Road injuries
- Malaria
- Noenatal preterm birth
- HIV/AIDS
- COPD
- Neonatal encephalopathy
- Tuberculosis
- Congenital defects
- Lung cancer
- Mental heath
- Diabetes
- Chronic kidney disease
- Other neonatal
- Alzheimer's disease
- Neonatal sepsis
- Liver cancer
- Falls
- Colorectal cancer
- Hypertensive heart disease
- Breast cancer

- Ischaemic heart disease
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- COPS
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- Noenatal preterm birth
- Breast cancer
- Falls
- Neonatal encephalopathy
- Malaria
- Neonatal Sepsis
- Other Noenatal

# Systemes de santé

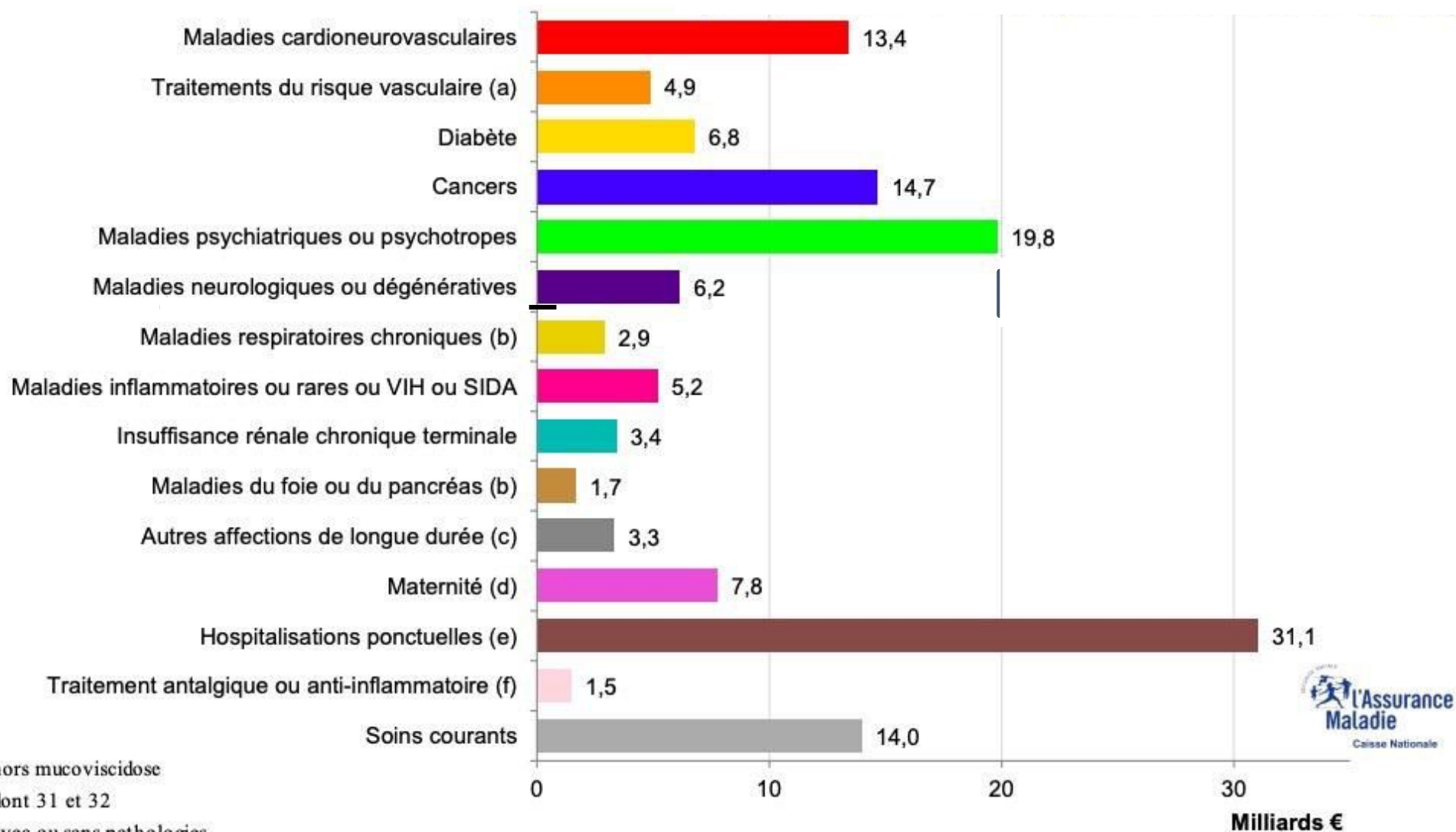
- La chronicité des maladies et l'augmentation associée de la consommation de soins et produits de la santé présentent une menace pour la soutenabilité des systèmes de couverture santé



Investir dans la prévention et dans la promotion de la santé, une nécessité pour maîtriser la croissance de cette charge et améliorer l'espérance de vie en bonne santé

Non-communicable diseases accounted for 73% of all global deaths in 2017, with over half of all deaths (28.8 million) attributable to just four risk factors: high blood pressure, smoking, high blood glucose, and high body-mass index ([www.thelancet.com](http://www.thelancet.com) Vol 392 November 10, 2018)

## 137 Mds d'euros remboursés par le Régime général



(b) hors mucoviscidose

(c) dont 31 et 32

(d) avec ou sans pathologies

(e) avec ou sans pathologies, traitements ou maternité

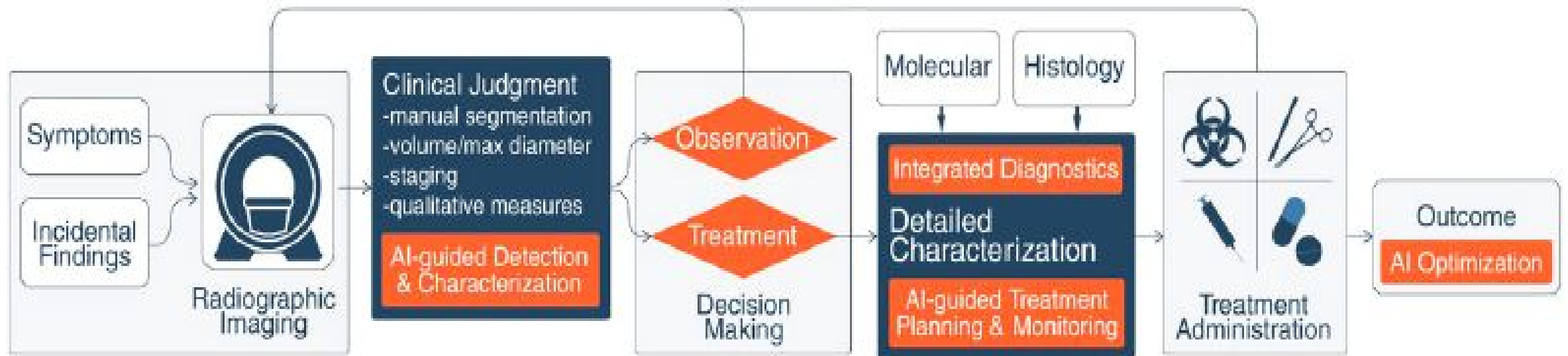
(f) hors pathologies, traitements, maternité ou hospitalisations

# Apports des nouveaux outils numériques / IA

## Applicabilité directe pour la prise en charge des maladies chroniques

” Imagerie

Artificial Intelligence in Cancer Imaging: Clinical Challenges and Applications



Current practice    Decision points    AI "areas of impact"

natural history or in response to treatment

and monitoring. However, the interpretation of the large volume of data that is

## Quelques REMARQUES

- La réflexion éthique doit être au cœur du soin et à tout niveau. Elle doit être enseignée tôt.
- La santé n'est pas un « produit » comme les autres.
- L'humain prime sur le droit ou le budget.
- Quelle vision avez-vous de votre métier ?
- La place de l'utilisateur de santé n'est pas assez reconnue.
- L'enjeu de la démocratie sanitaire.



COMITÉ CONSULTATIF NATIONAL D'ÉTHIQUE  
POUR LES SCIENCES DE LA VIE ET DE LA SANTÉ



Conférence JFR 2019 du Pr  
Delfraissy  
Président du CCNE

# Accident Vasculaire Cérébral : AVC

**Un Français est victime d'un AVC toutes les 4 minutes**

**soit environ 150 000 AVC chaque année.**

**Première cause de mortalité chez la femme devant le cancer du sein**

**Première cause de handicap acquis chez l'adulte**

Le coût de la prise en charge de l'AVC pour l'Assurance maladie a été estimé en 2017

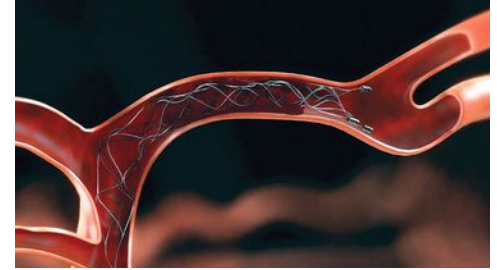
**à 3 milliards d'euros et de 8,6 milliards en incluant le coût du handicap post-AVC.**



# Épidémiologie dans le monde

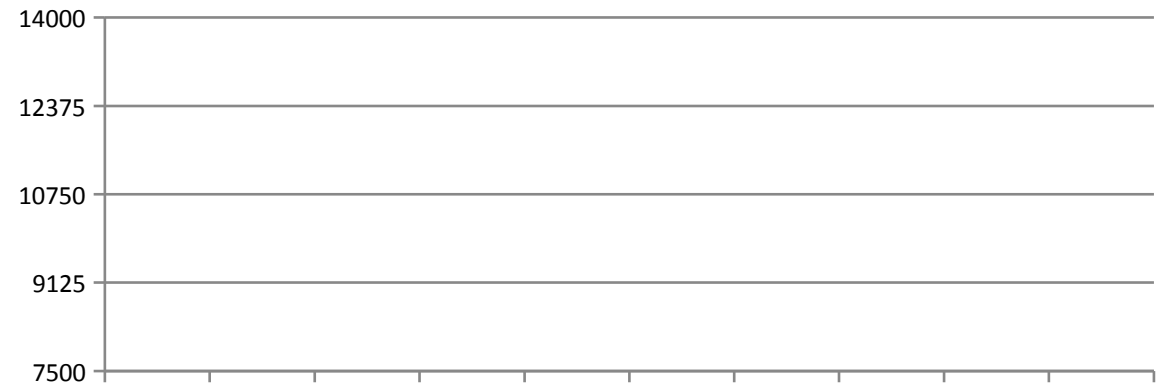
- **Plus de 13 millions d'AVC par an dans le monde :**
  - 9,5 millions d'infarctus cérébraux par an
  - Plus de 5 millions de décès annuels
  - 18 millions de patients vivent avec des séquelles d'AVC
  
- **Les perspectives de la situation à 15 ans en Europe :**
  - Augmentation de 1,8 à 3 millions d'AVC (+66%)
  - Augmentation de 3,7 à 4,6 millions de patients en situation de handicap (+33%)

- A partir de 2015, cinq études scientifiques sur l'AVC (MR CLEAN, EXTEND-IA, ESCAPE, SWIFT-prime, THRACE) ont validé une innovation thérapeutique dans le traitement des AVC : **la thrombectomie mécanique**



- Le **contexte d'urgence vitale** de ces interventions a **profondément modifié le parcours le cadre et les conditions de travail des équipes soignantes**

Projection de progression de la thrombectomie



- ✘ à l'origine de nouvelles organisations
- ✘ à l'origine de nouveaux métiers



# ACCIDENT VASCULAIRE CÉRÉBRAL

## CHAQUE MINUTE COMPTE



Vous ressentez  
**brutalement**

- une **faiblesse** d'un côté du corps,
- une **paralysie** du visage, du bras et/ou de la jambe,
- une **difficulté** à parler...

**c'est peut-être  
un AVC**

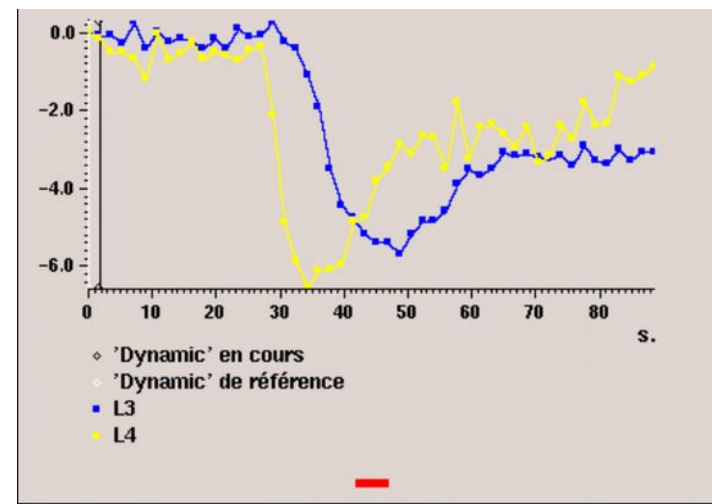
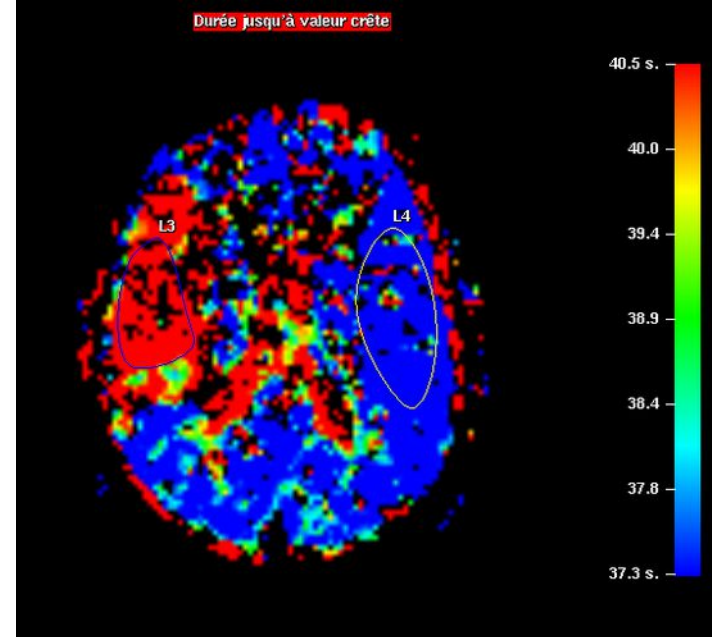
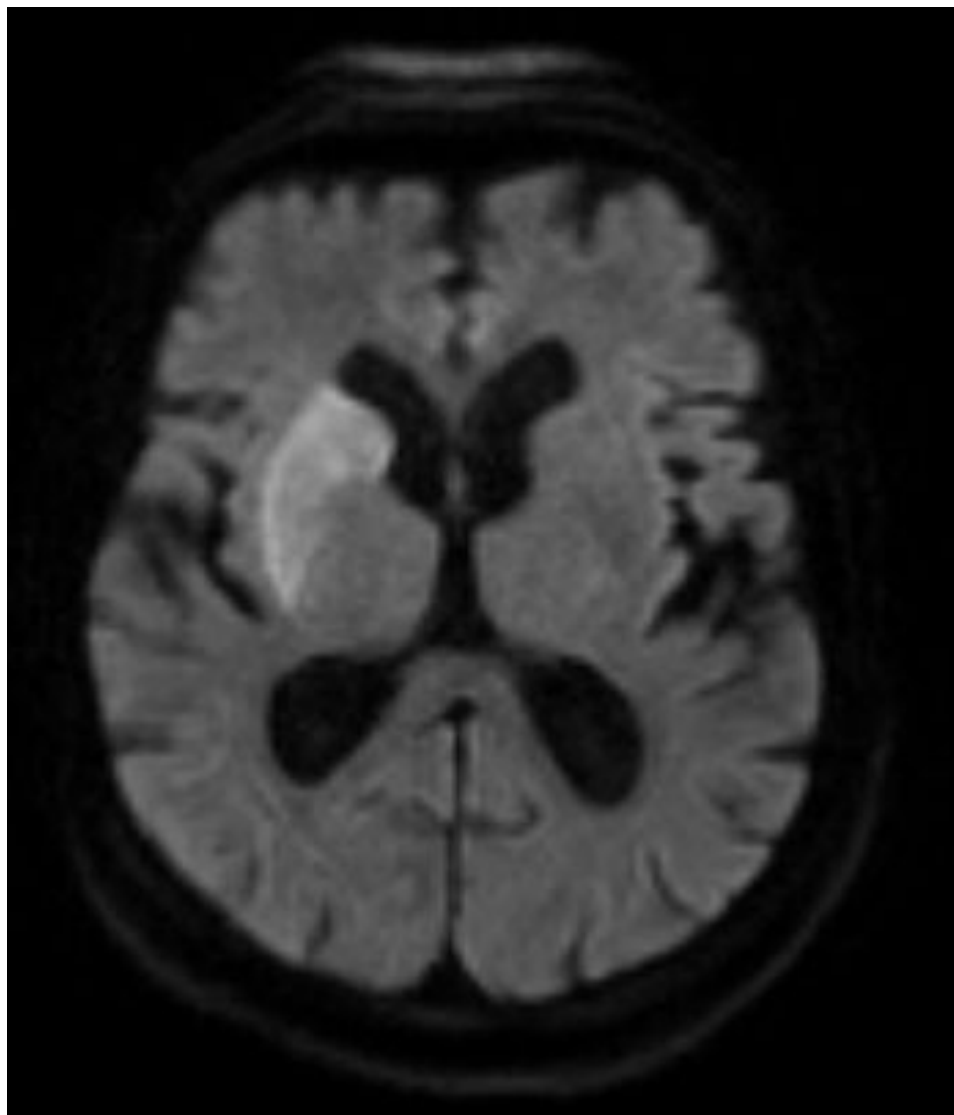


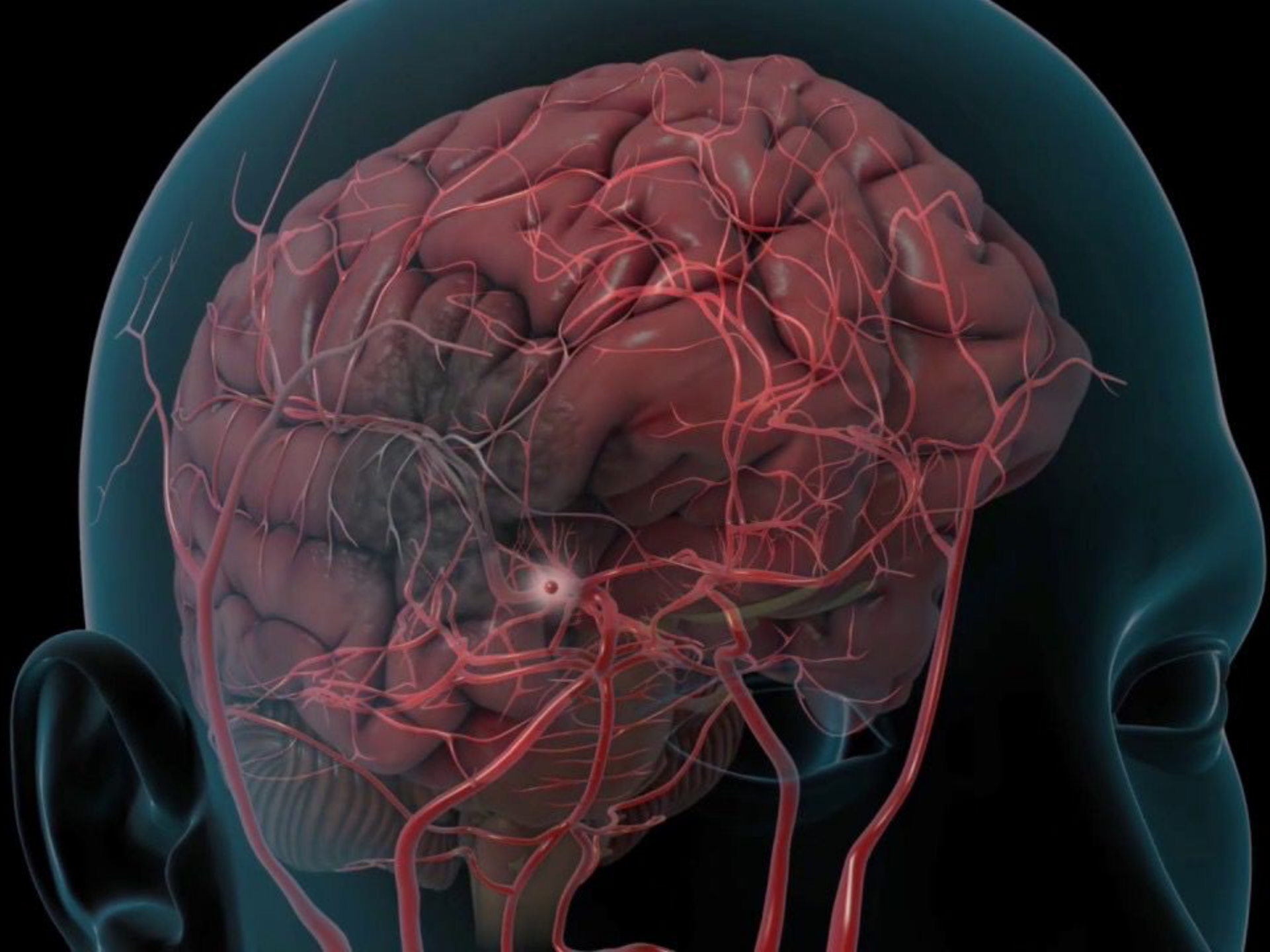
**APPELZ VITE LE**

**15**



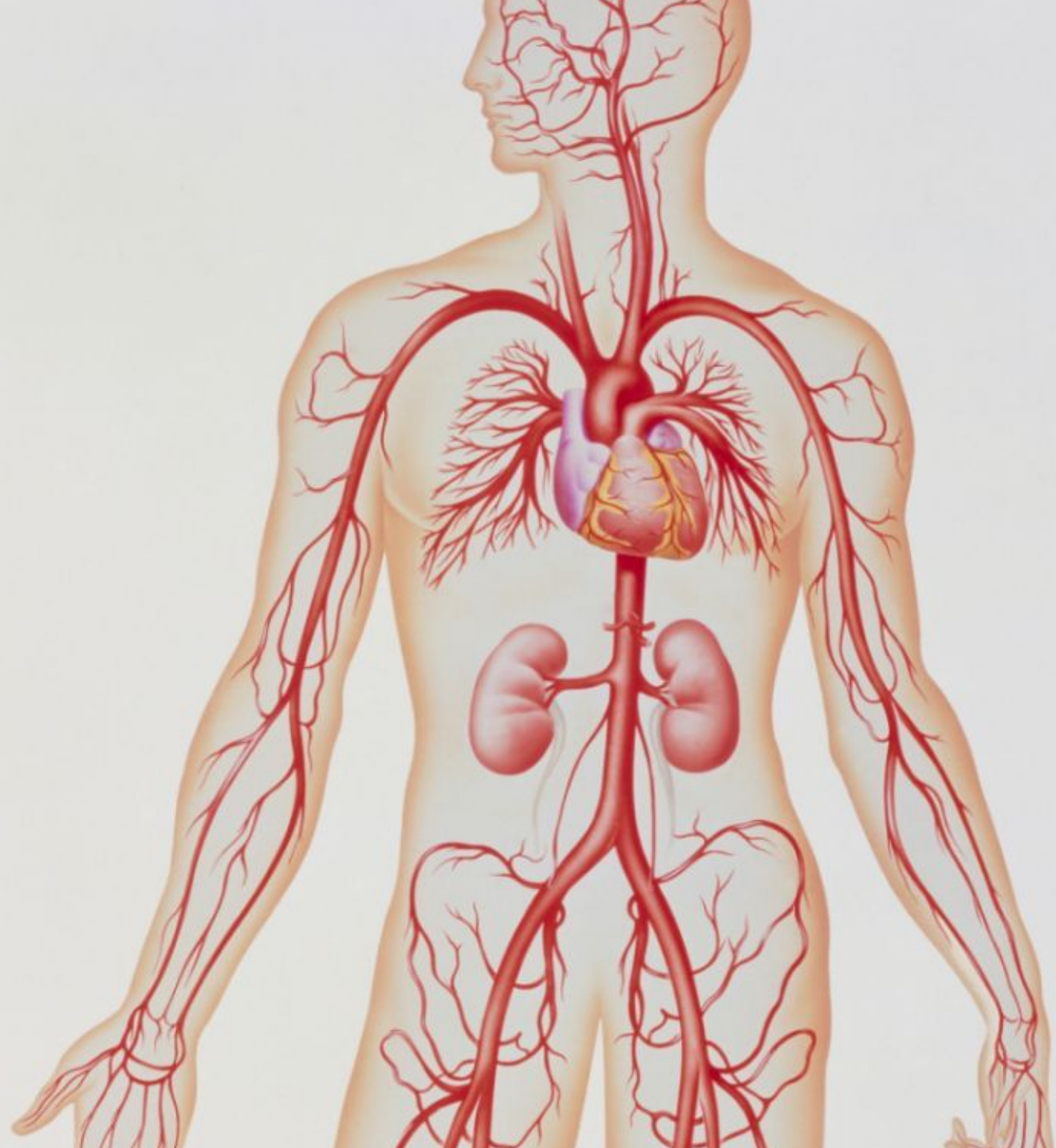


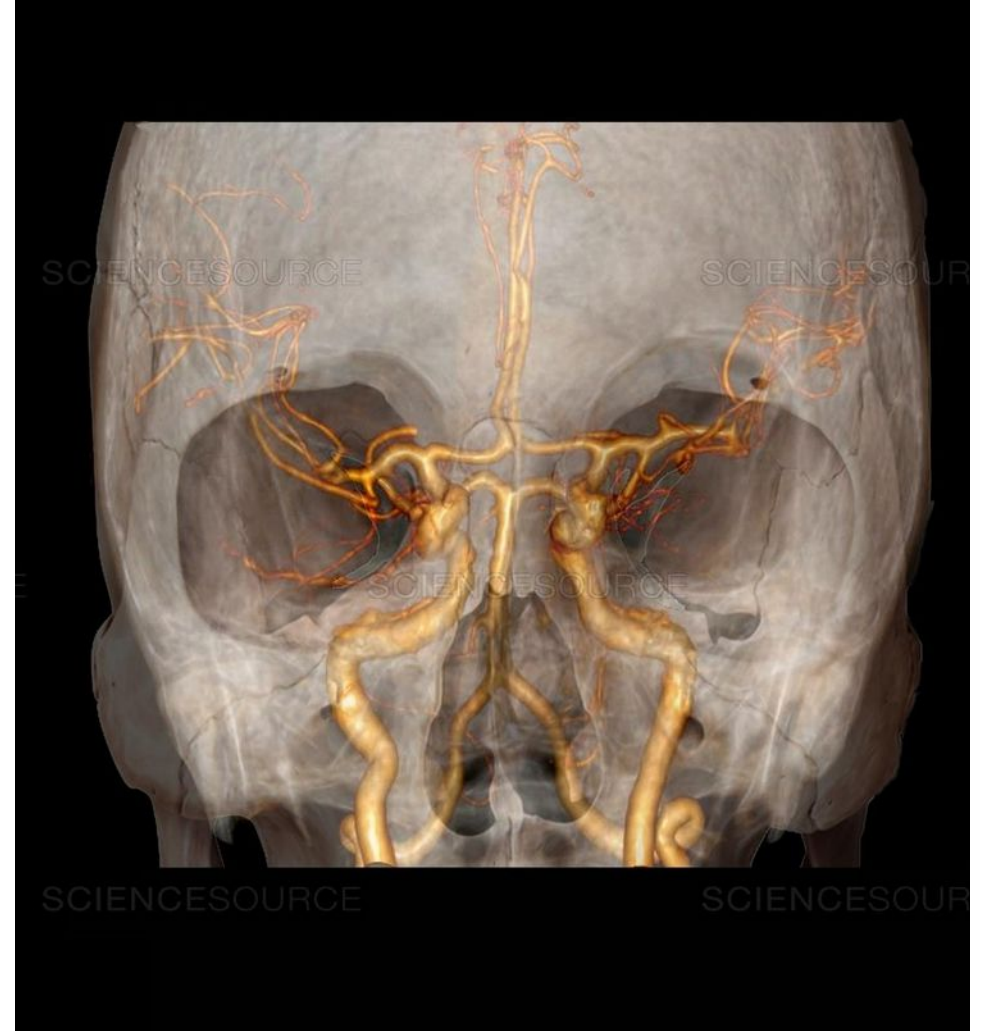


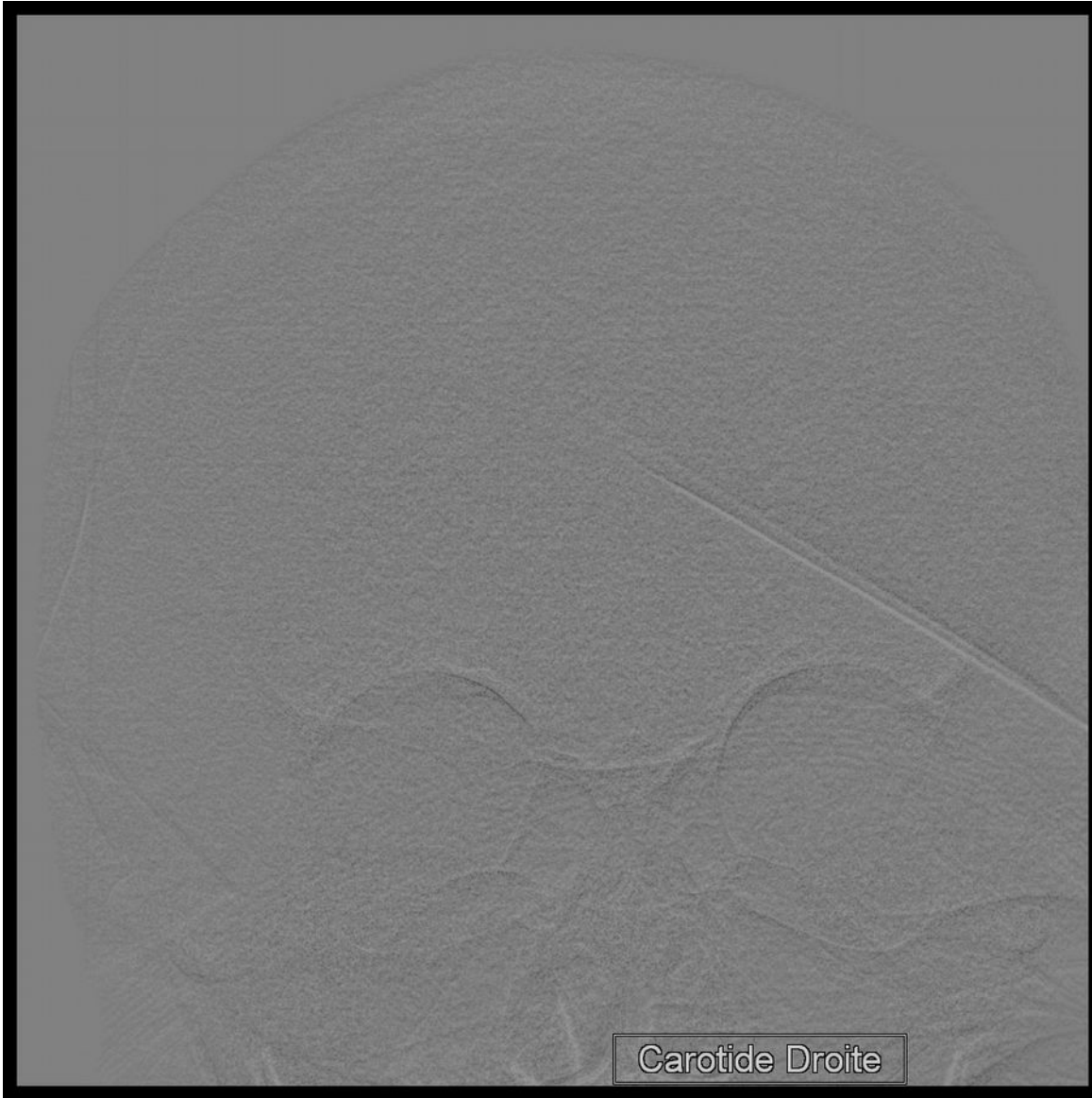


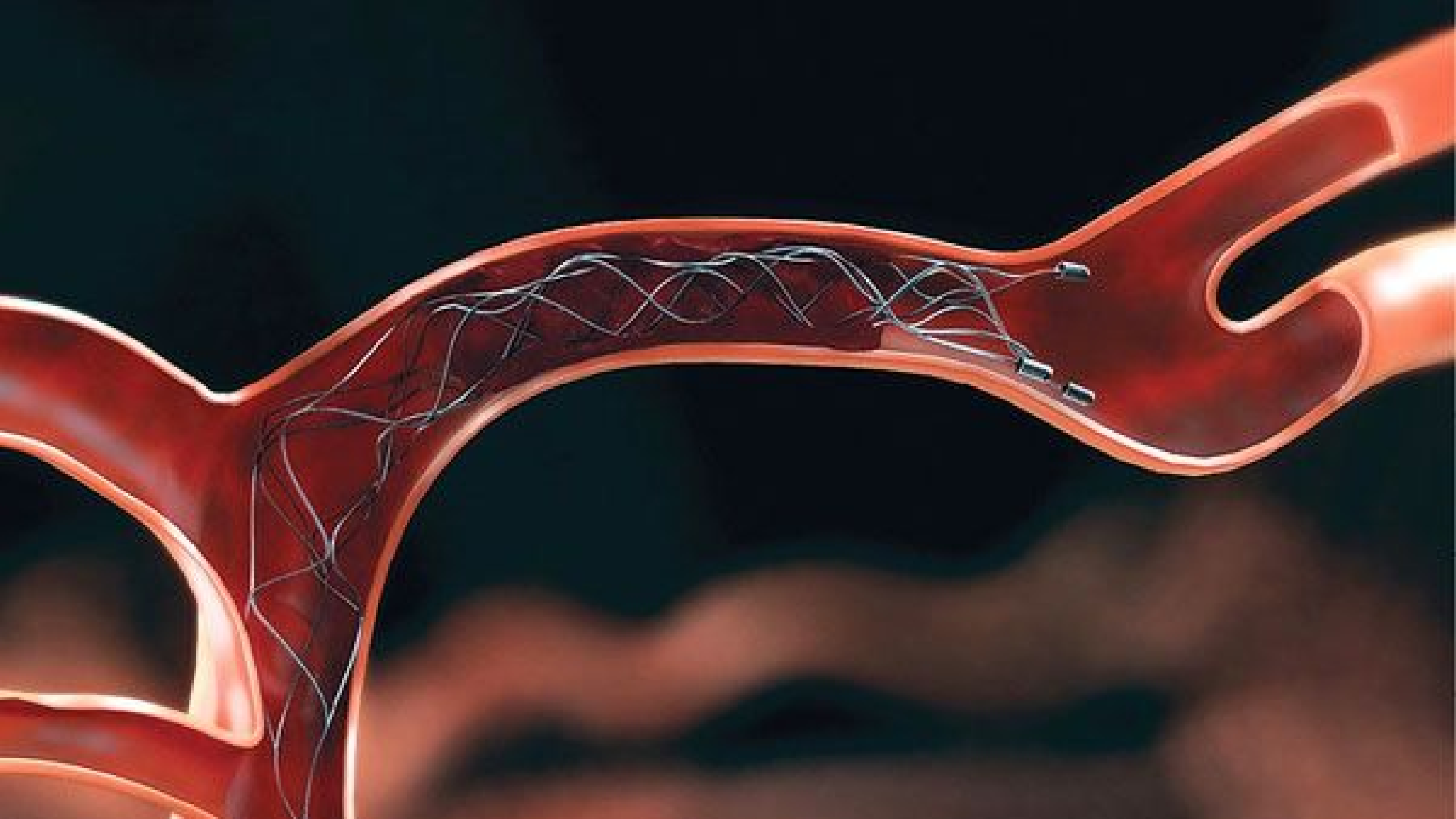


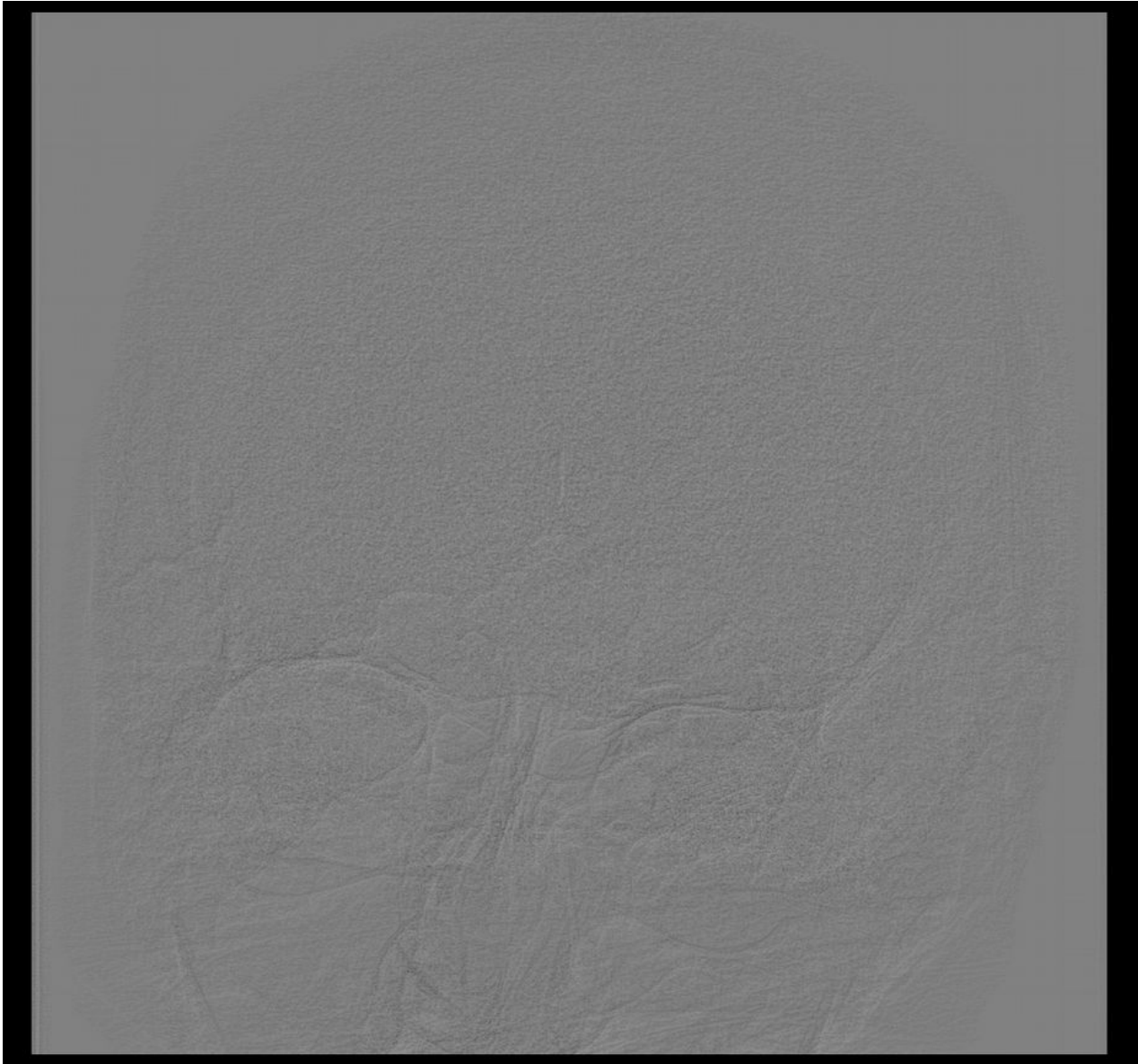










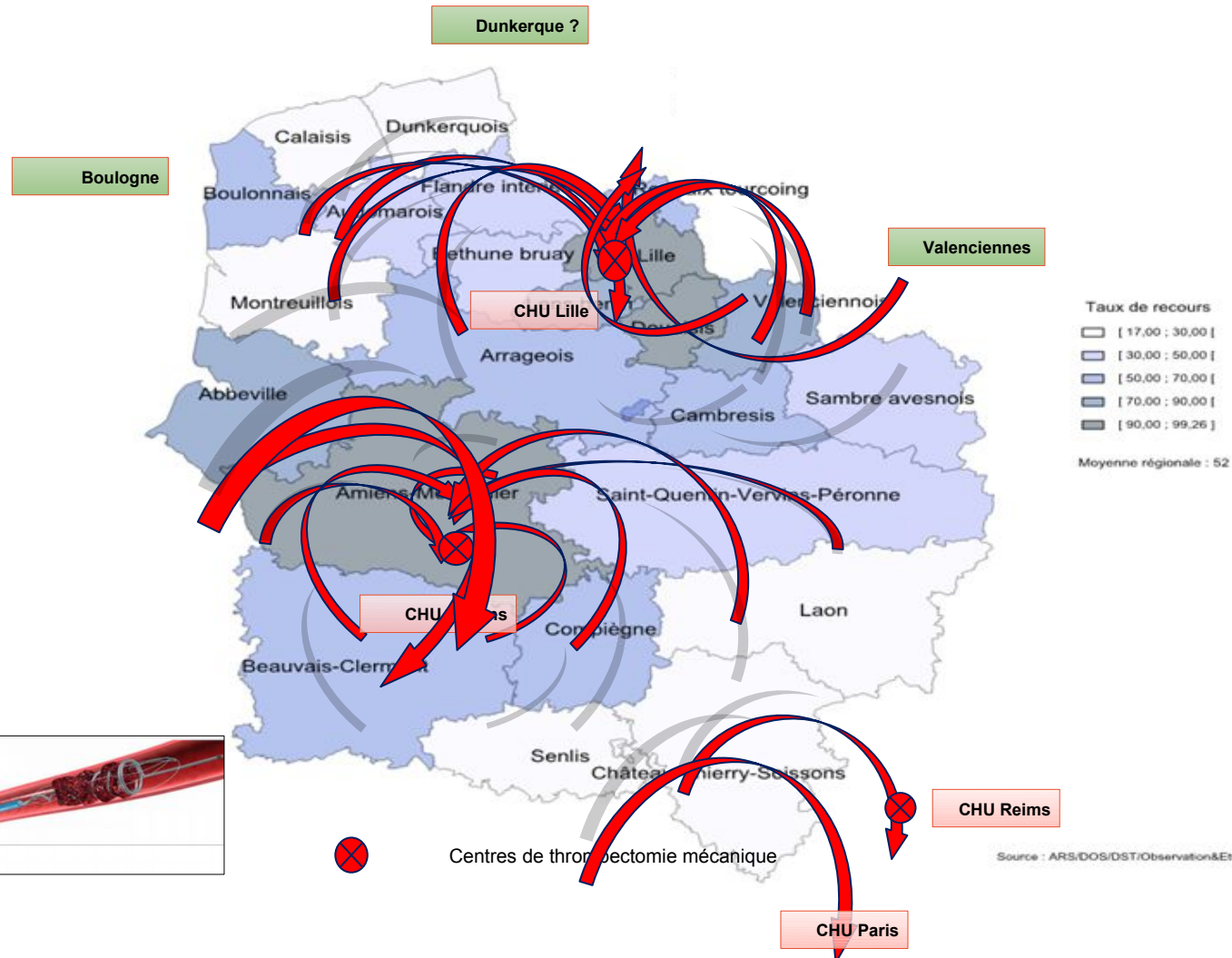




TELE AVC et thrombectomie

Délais d'accès au centre de reperfusion

## Recours à la thrombectomie



Centres de thrombectomie mécanique



# Applications of 7Tesla MRI in Neuroradiology

1- Neurodegenerative disorders

2- Neurovascular disorders

3- Epilepsy

4- Psychiatry

# 7T-MRI and neurological diseases

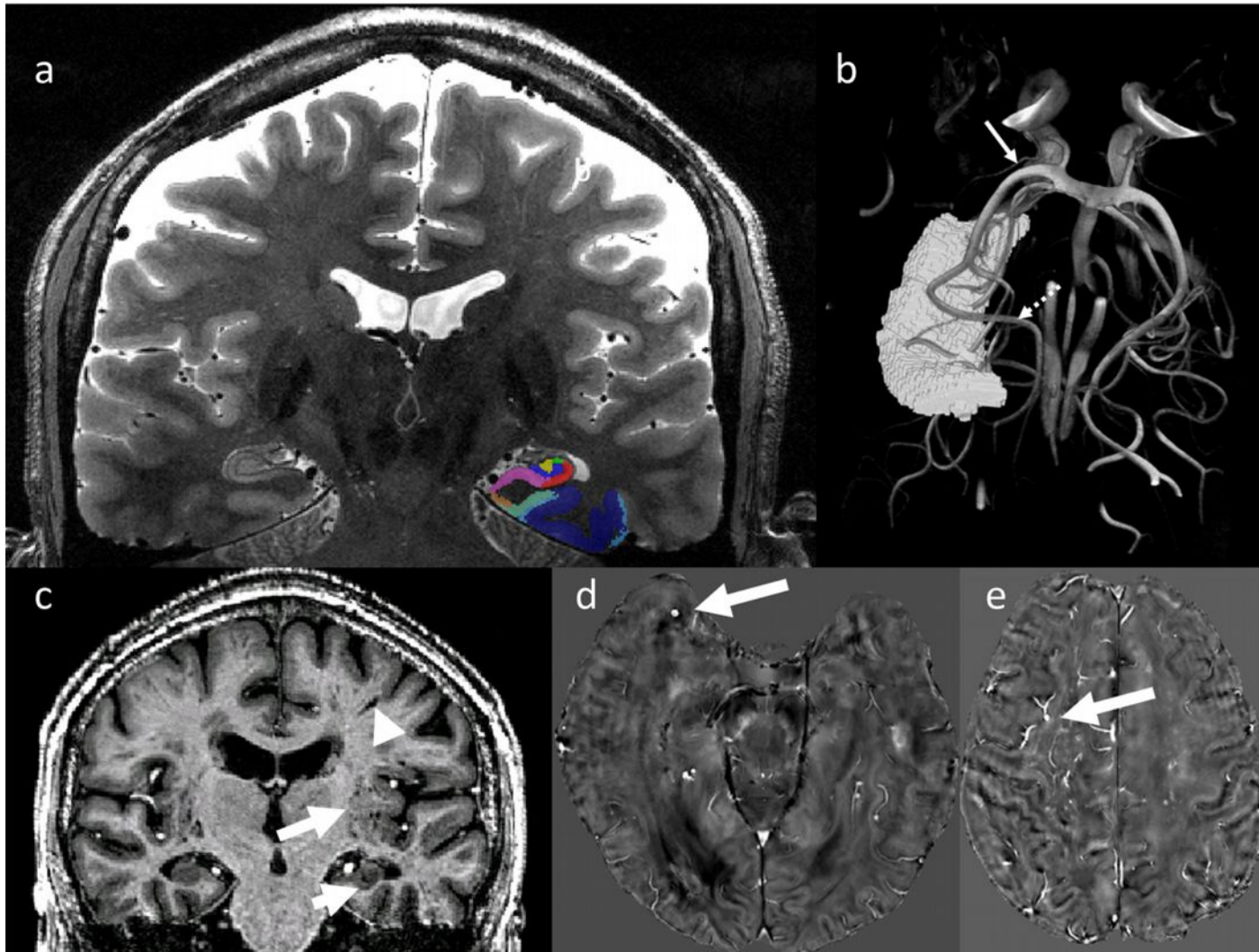
**1- Neurodegenerative disorders**

2- Neurovascular disorders

3- Epilepsy

4- Psychiatry

# Alzheimer Disease (AD)



**Higher SNR and spatial resolution allowing a better visualization of AD MRI biomarkers :**

a) Hippocampus sub-segmentation

b) Hippocampus vascularization pattern

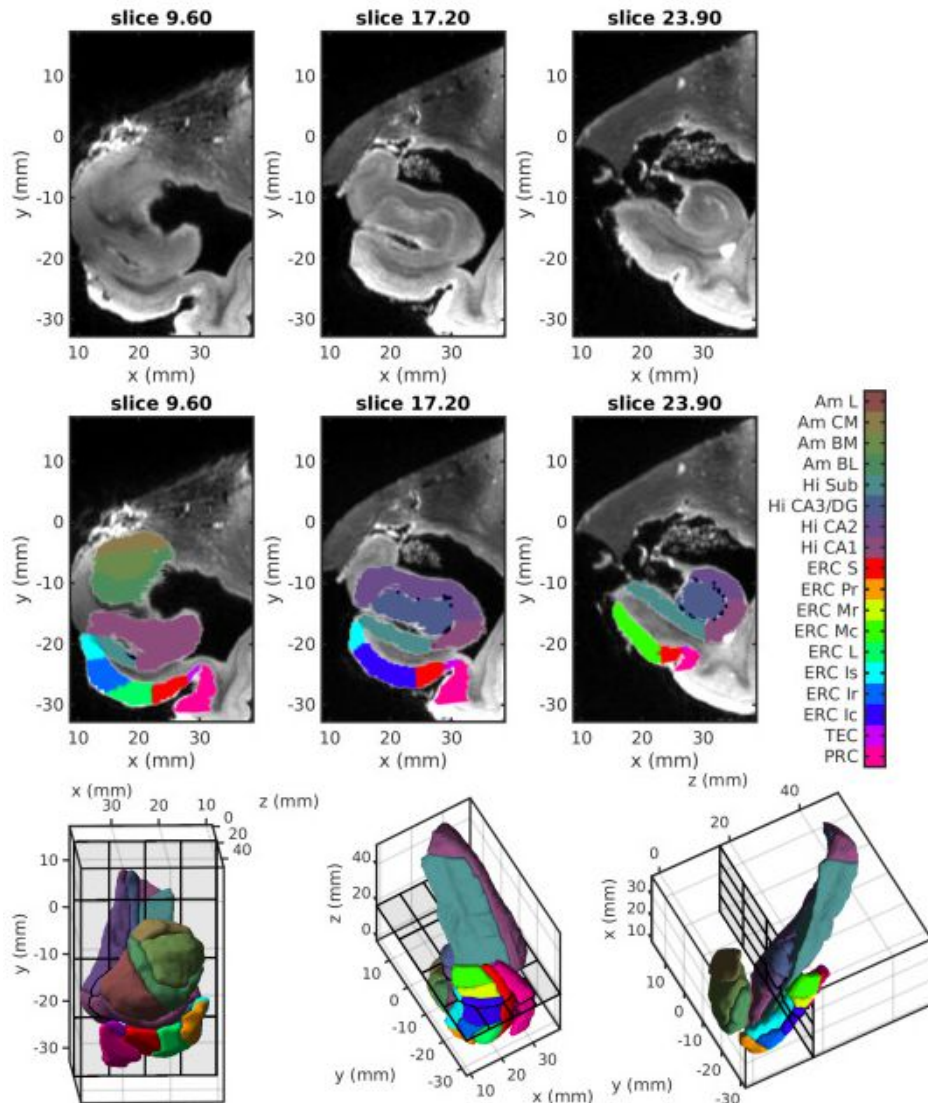
c) Perivascular spaces (Virchow-Robin)

**Increased nuclear magnetization and susceptibility effects:**

d et e) Microbleeds on QSM imaging

... and also brain iron load analysis

# Alzheimer Disease (AD)

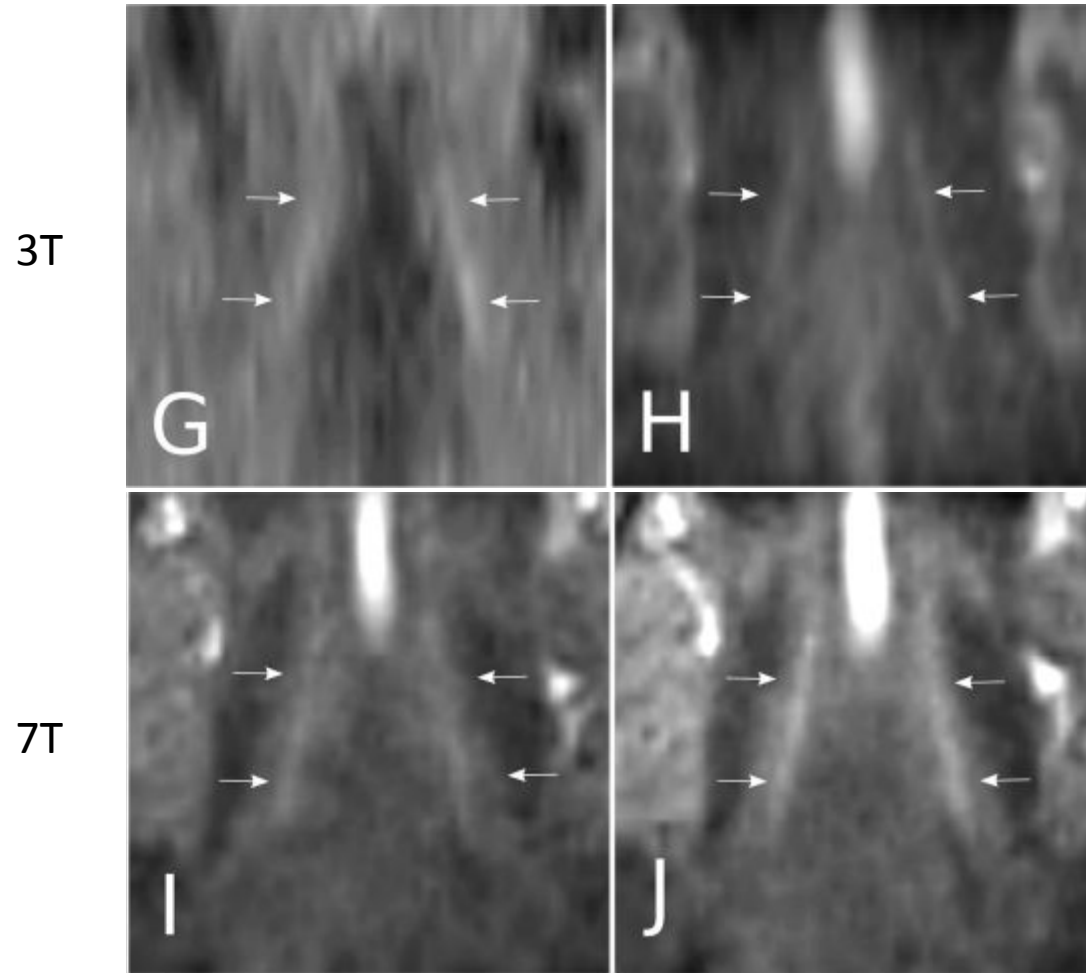


**Earlier detection of presymptomatic stages to improve management**

Example:

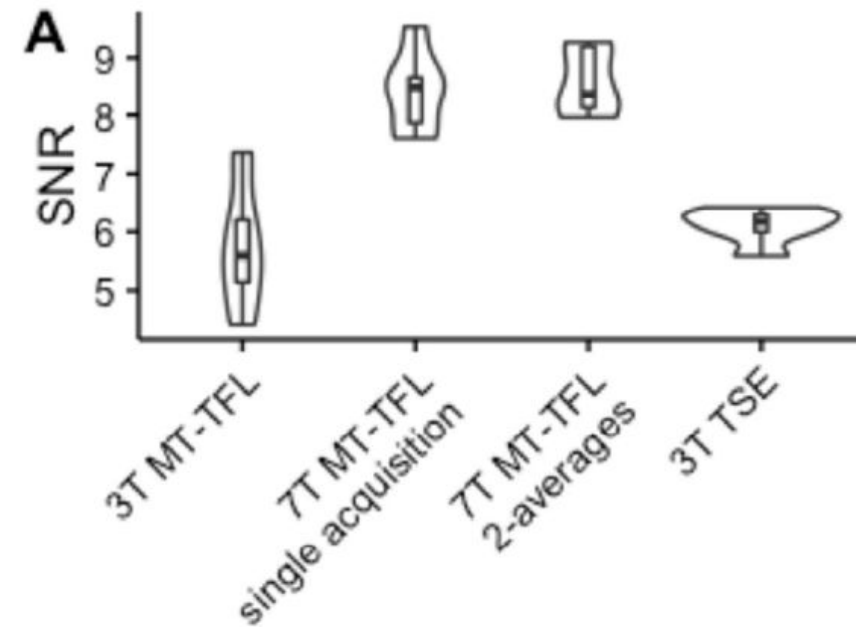
Early changes in entorhinal cortex thickness not visible at 3T.

# Alzheimer Disease (AD)



## Towards new imaging biomarkers

Visualization of the locus coeruleus, the "noradrenalin factory" involved in the early stages of AD.



# Parkinson Disease



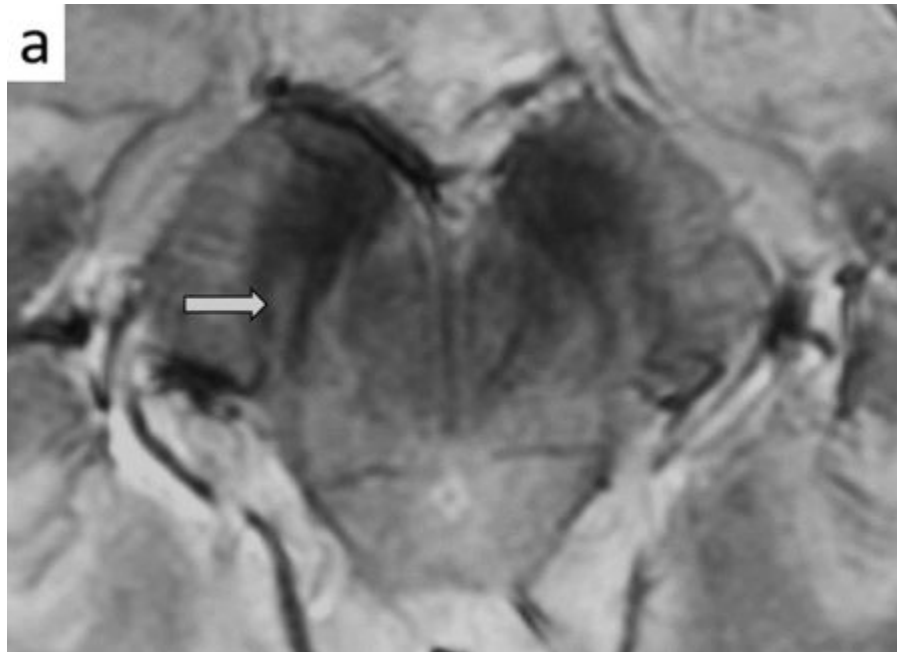
**Improving the diagnostic performance of degenerative parkinsonian syndromes:**

Better sensitivity (100%) and specificity (92.3-100%) thanks to improved nigrosome 1 analysis

**Improved patient follow-up:**

Iron quantification with QSM sequences

# Parkinson Disease

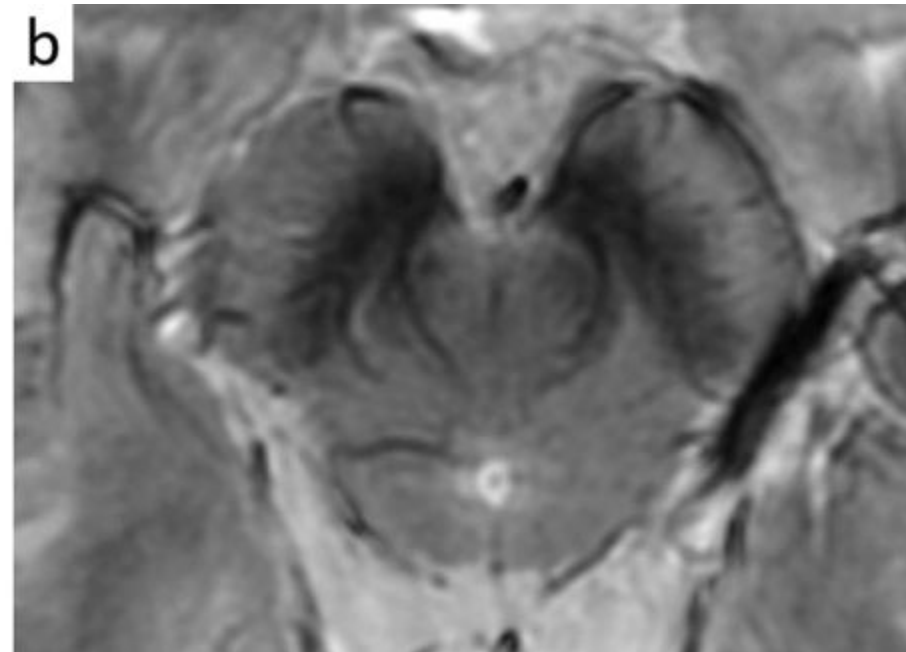


Rapid Eye Movement Behavior  
Disorder

+

Visible Nigrosome 1:

**No Parkinson developed during**



Rapid Eye Movement Behavior  
Disorder

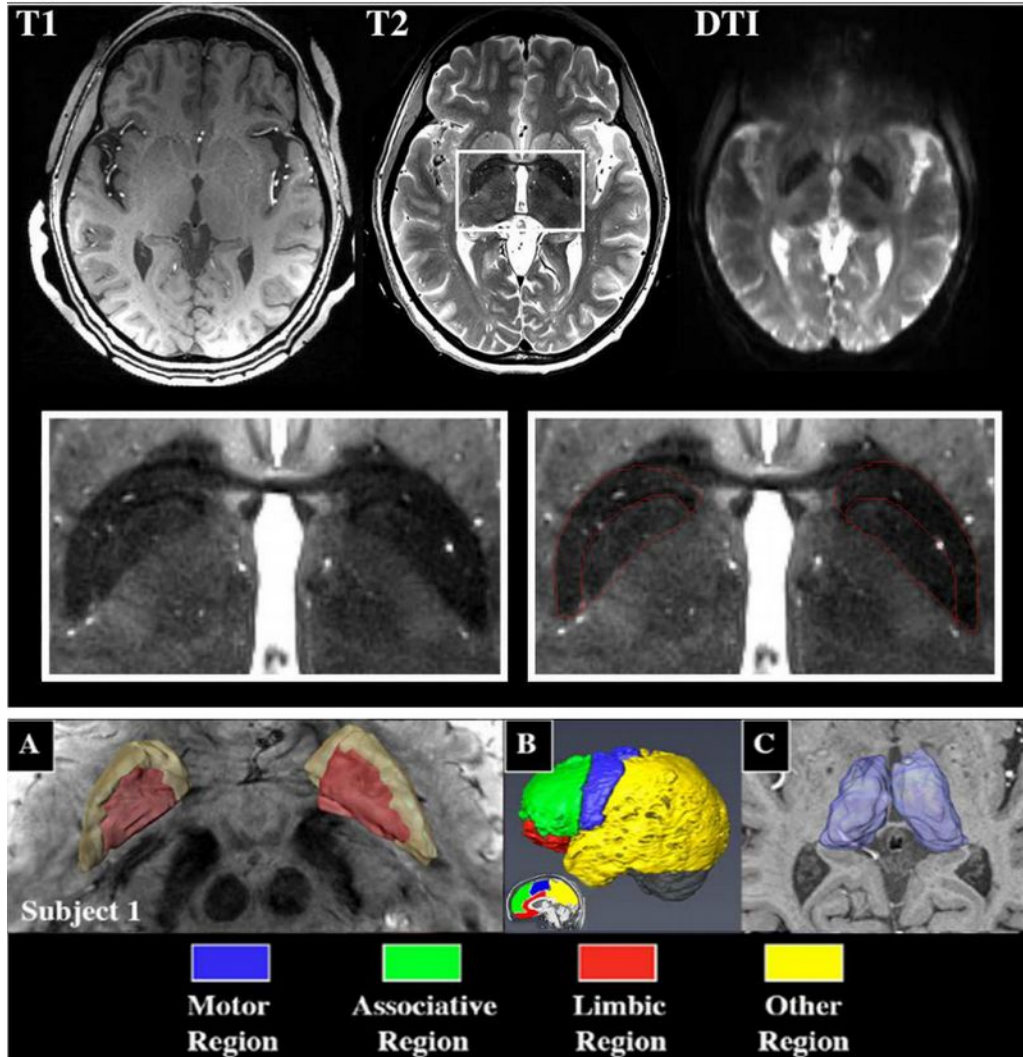
+

No visible Nigrosome 1:

Düzel et al., 10.1186/s41747-021-00221-5

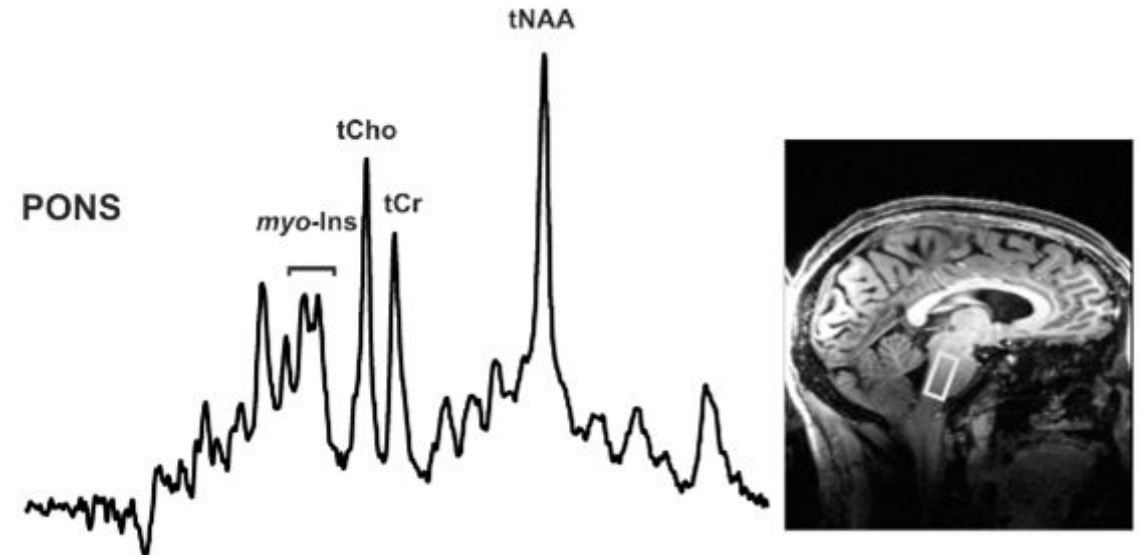
**Parkinson developed during follow-up**

# Parkinson Disease



Improved positioning of DBS probes by basal ganglia parcellation

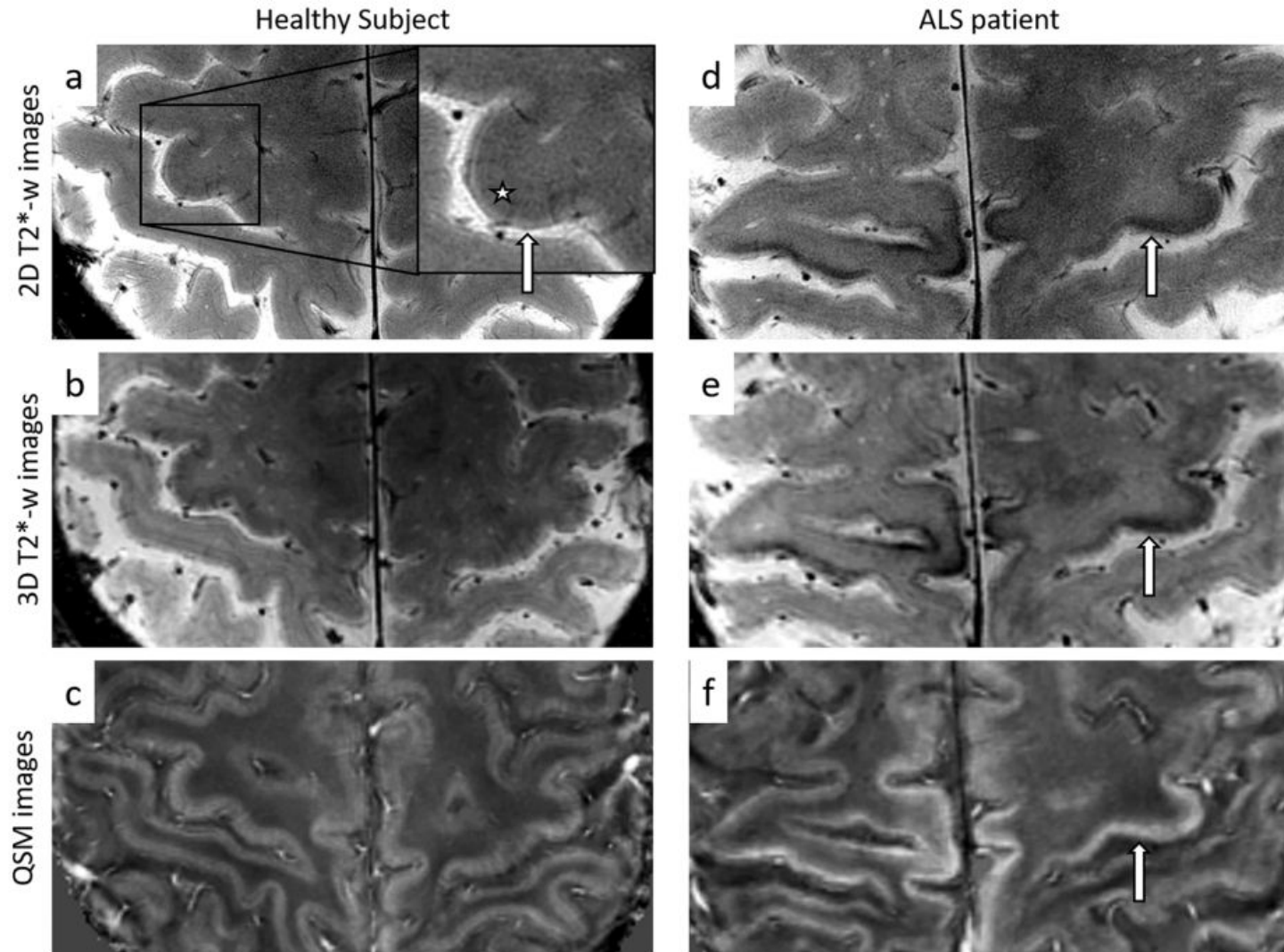
Progress in the understanding of Parkinson pathophysiology through new potentials (e.g. GABA spectroscopy)



Emir et al., 10.1371/journal.pone.0030918



# And many other potential targets



**Example of amyotrophic lateral sclerosis (ALS)**

Better visualization of motor cortex signal anomalies using QSM

# 7T-MRI and neurological diseases

1- Neurodegenerative disorders

**2- Neurovascular disorders**

3- Epilepsy

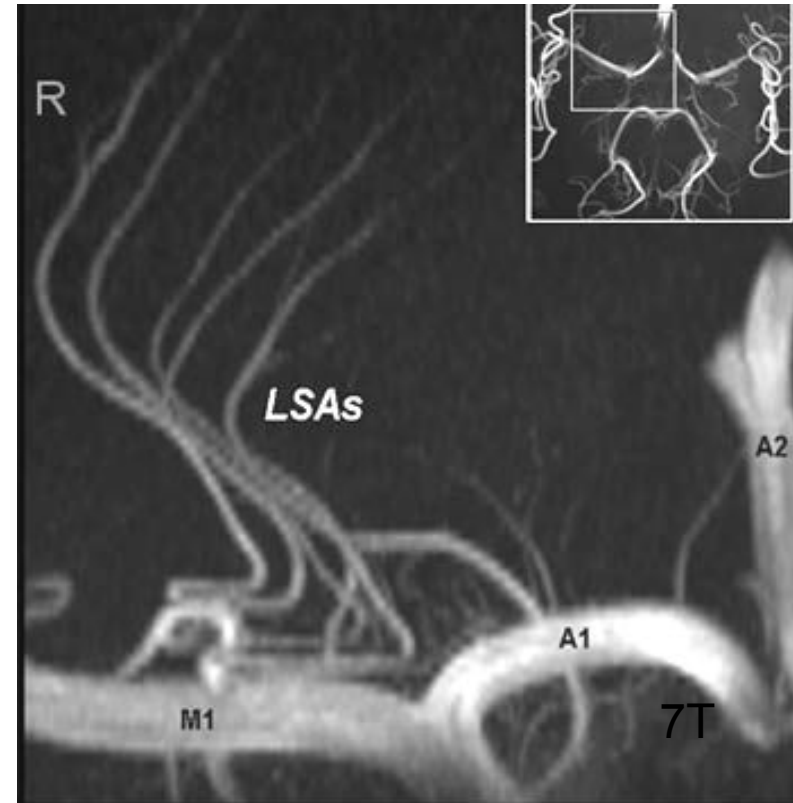
4- Psychiatry

# Cerebrovascular diseases and 7T MRI

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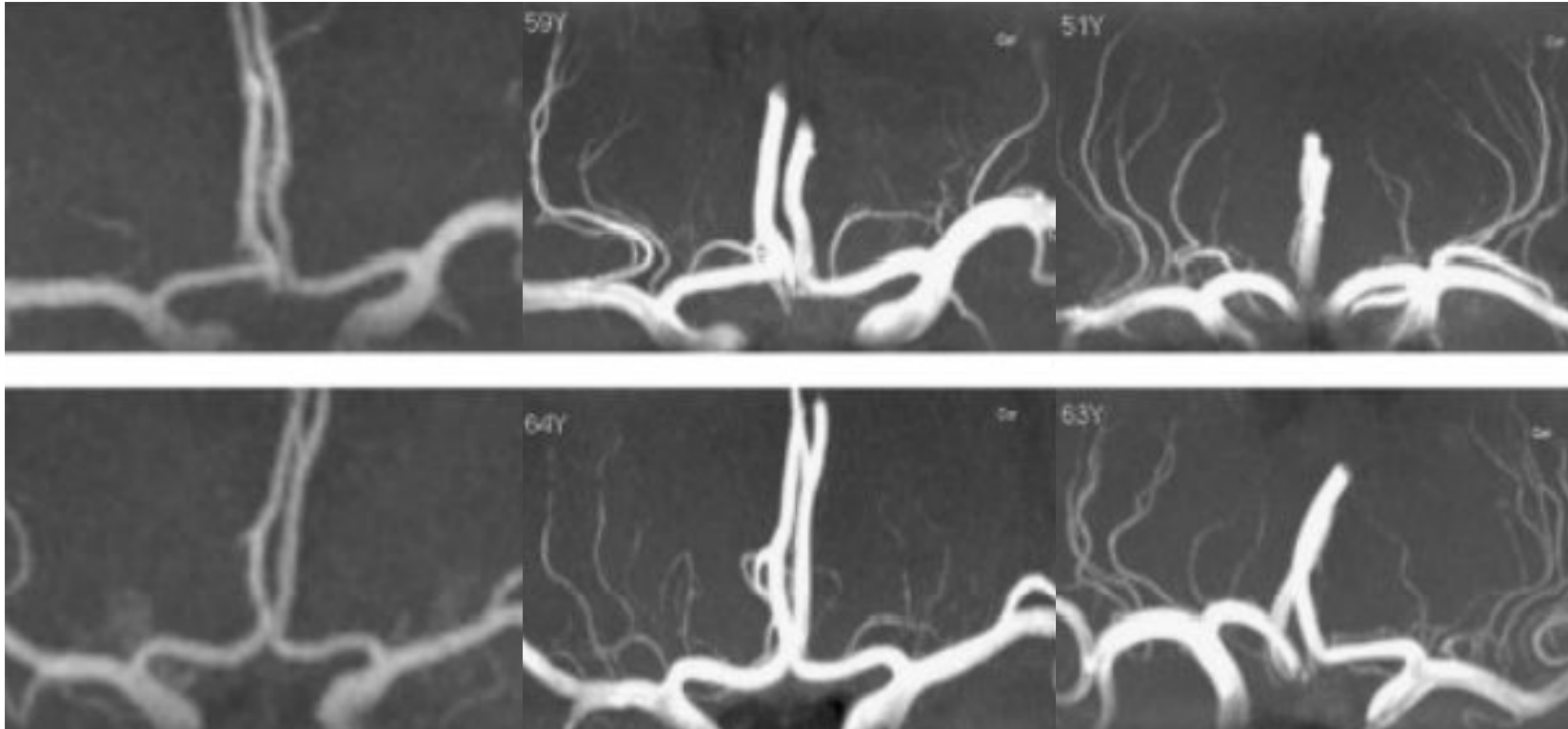
## Main features

- Higher SNR which can be transferred into high spatial resolution, as well as a high CNR.
  - Visualization of the lumen of much smaller intracranial vessels.
- Arterial vessel walls beyond the circle of Willis become visible with high-resolution vessel wall imaging.
  - Brain parenchyma can now be visualized on a submillimeter scale.



# Perforating arteries

Decreased number of perforating arteries in patients with lacunar infarcts



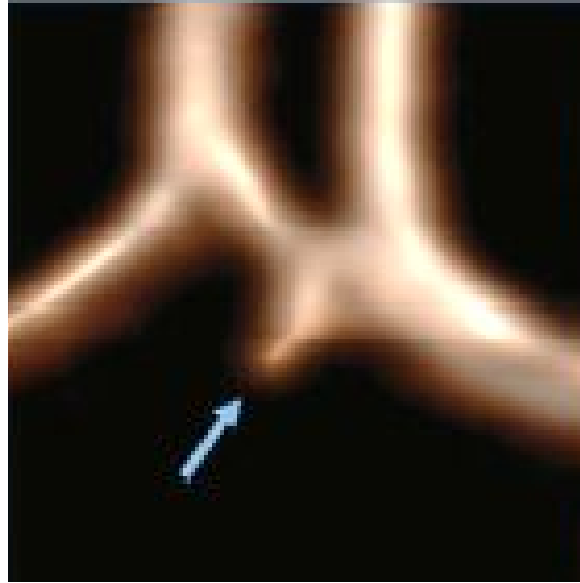
1.5 MRI  
Lacunar infarcts

7T MRI  
Lacunar infarcts

7T MRI  
Healthy patients

# Intracranial aneurysms

Better distinction between aneurysms and vascular anatomic variants



3T MRI



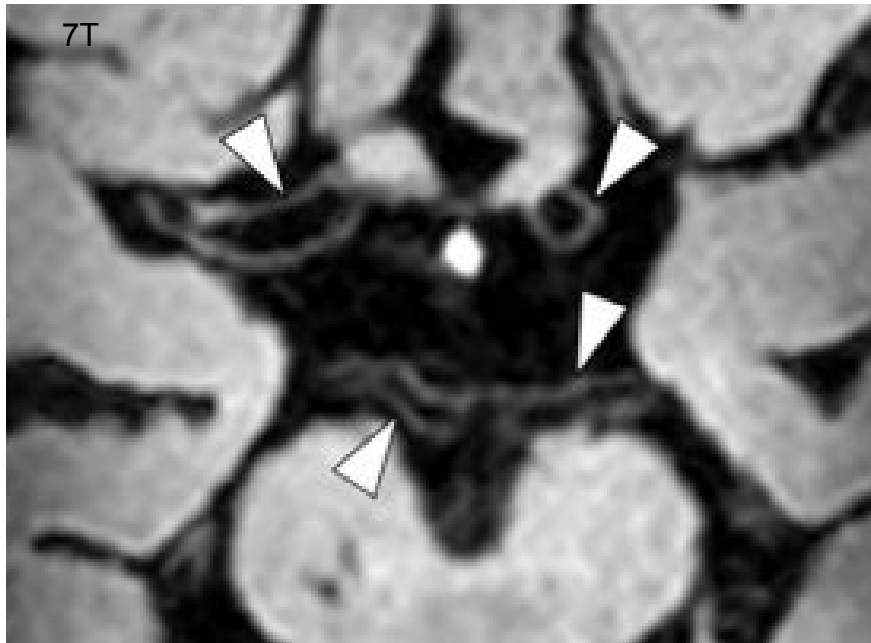
7T MRI

7T MR imaging depicts an infundibulum emerging from the anterior communicating artery

*Radojewski D et al. Clinical Implementation of 7T MRI for the Identification of Incidental Intracranial Aneurysms versus Anatomic Variants. AJNR 2021*

# Atherosclerosis

Better visualization of the pathologic vessel wall



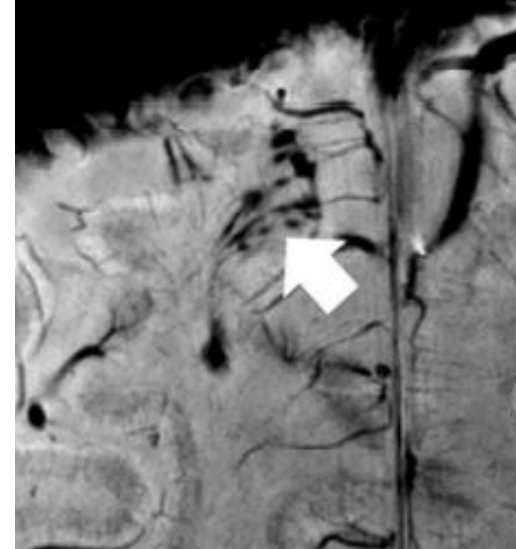
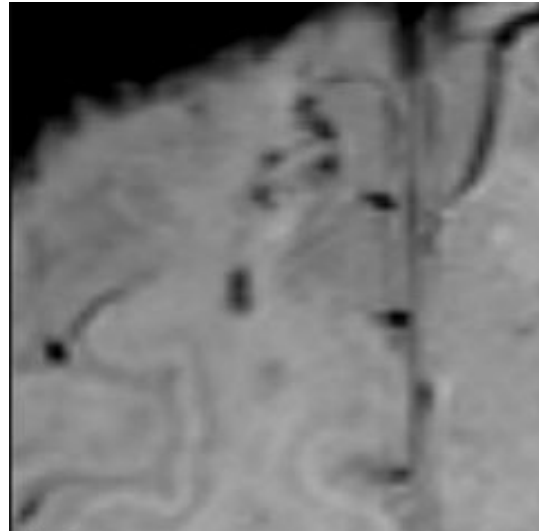
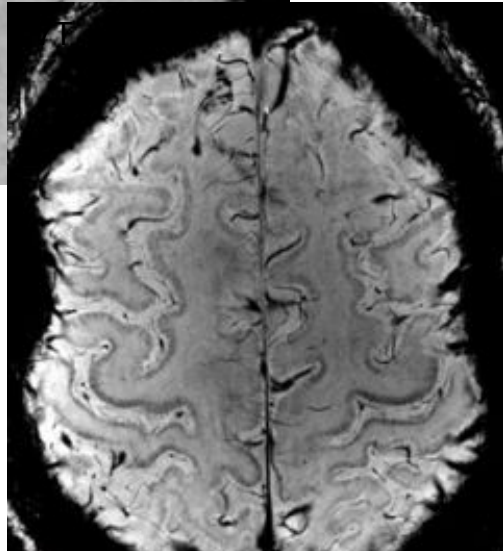
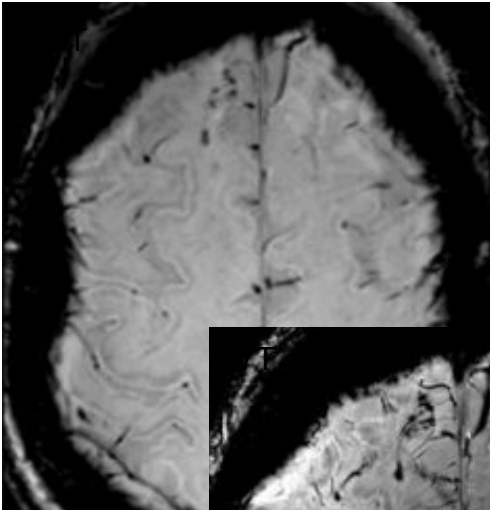
Healthy patient



Carotid plaque (arrowhead)

# Microhemorrhages

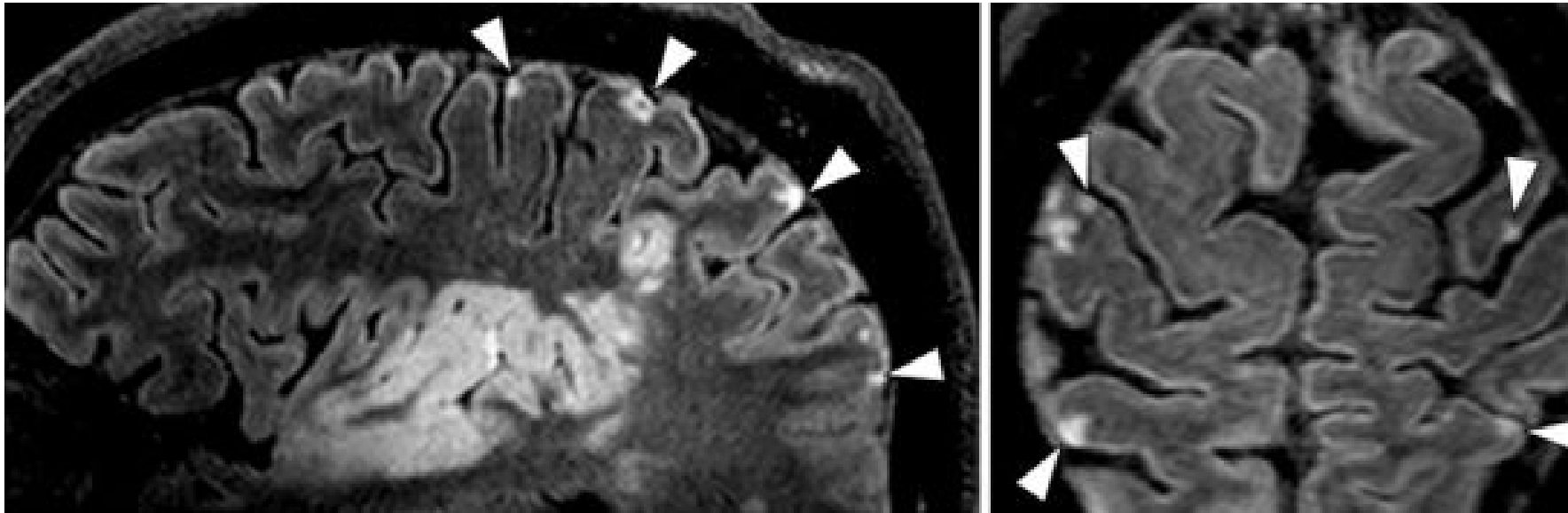
Better detection of microhemorrhages in SWI at 7T MRI that may shows a close contact of brain lesions with trans-cerebral veins



Post-traumatic diffuse axonal lesions

# Cerebral microinfarcts

Better detection of microinfarcts on 7T contrast-enhanced 3 FLAIR imaging as compared to 3T MRI

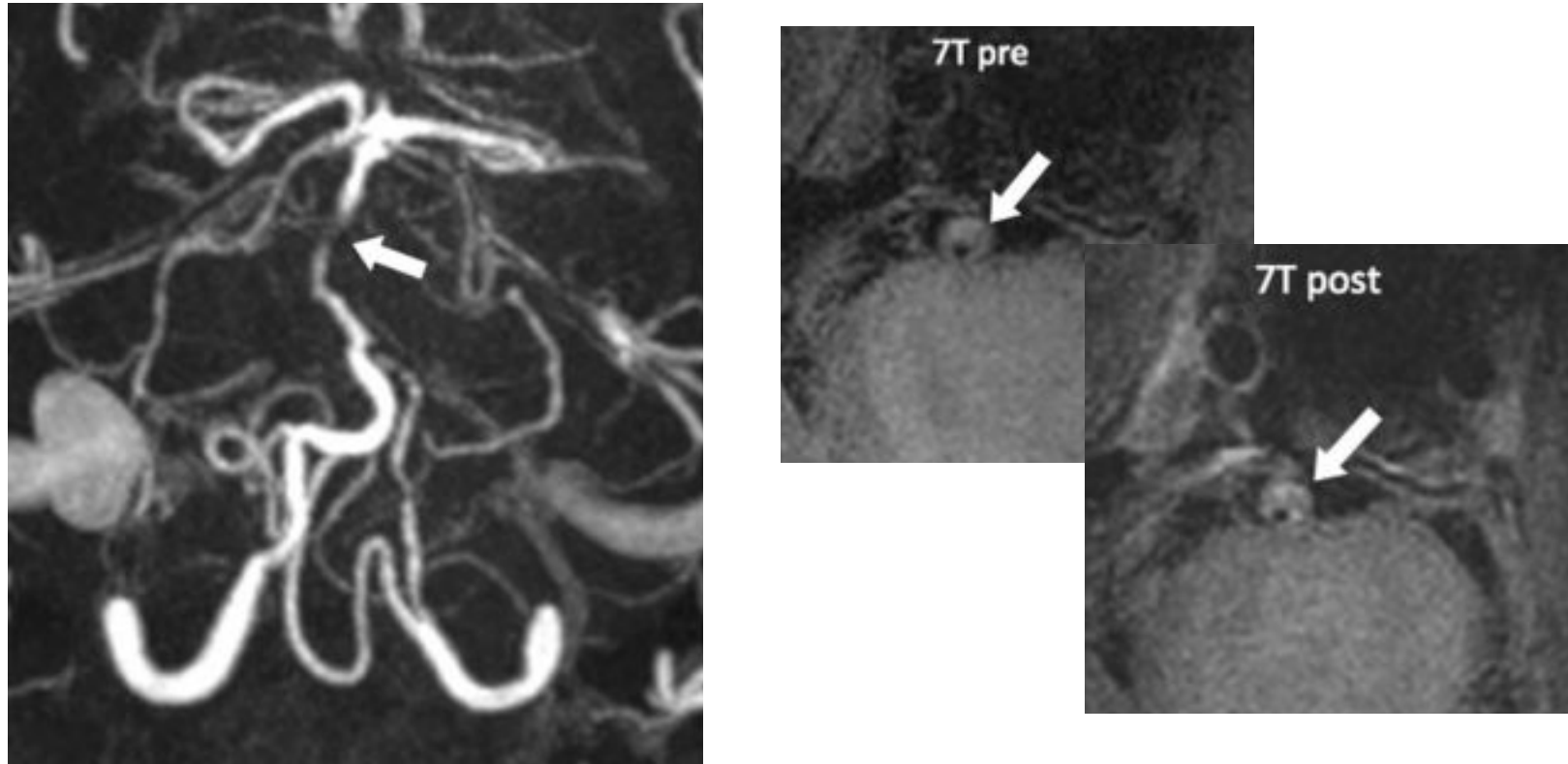


68- year-old man with a large right-sided temporoparietal ischemic infarction



# Prediction of atherosclerotic plaque rupture

Superior vessel wall characterization of the plaque compared with 3T



*Rutland JW et al. Emerging Use of Ultra-High-Field 7T MRI in the Study of Intracranial Vascularity: State of the Field and Future Directions. AJNR 2020*

# 7T-MRI and neurological diseases

1- Neurodegenerative disorders

2- Neurovascular disorders

**3- Epilepsy**

4- Psychiatry

# EPILEPSY « MRI-negative »

- Allows for better lesion detection (25% > 1.5 or 3T-MRI)
  - Better characterization / delineation of lesions
- Especially for abnormalities of cortical development (focal cortical dysplasia: 50% of drug-resistant epilepsy, 40% « MRI-negative »)

*1 De Ciantis et al. Epilepsia 2016; Veersema et al. Epilepsia Open 2017; Feldman et al. PLoS ONE 2019; Sharma et al. Epi & Behaviors reports 2021*

*2 Springer et al. Invest Radiol 2017; Obusez et al. Neuroimage 2018; Wang et al. Front Neurol 2021*

*3 De Ciantis et al. AJNR 2015; Sun et al. Neuroradiology 2018; Guye et al. Rev Neurol 2019*

# MRI 7T and Epilepsy

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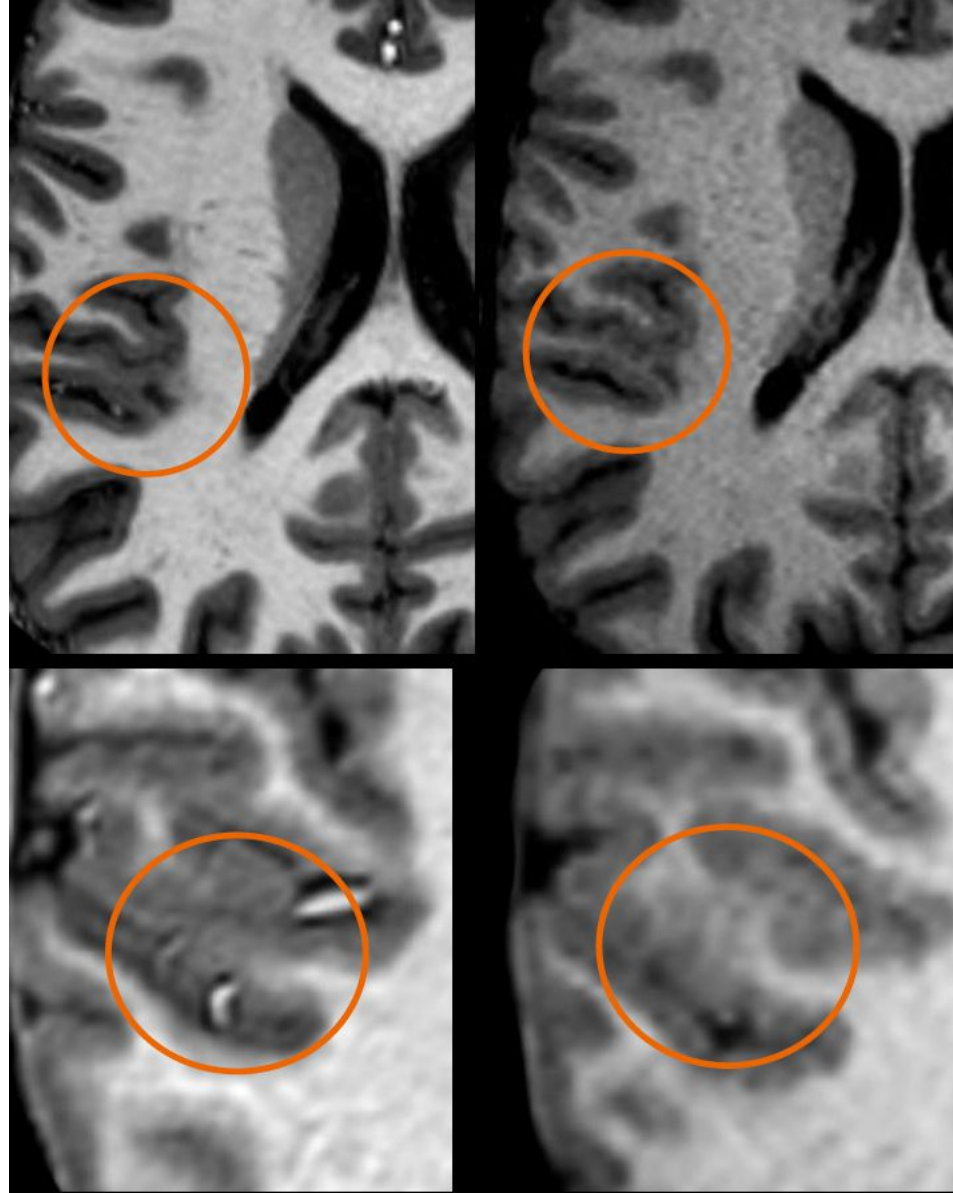
December 22, 2020 [VIEWS & REVIEWS](#)

## 7T Epilepsy Task Force Consensus Recommendations on the use of 7T in Clinical Practice

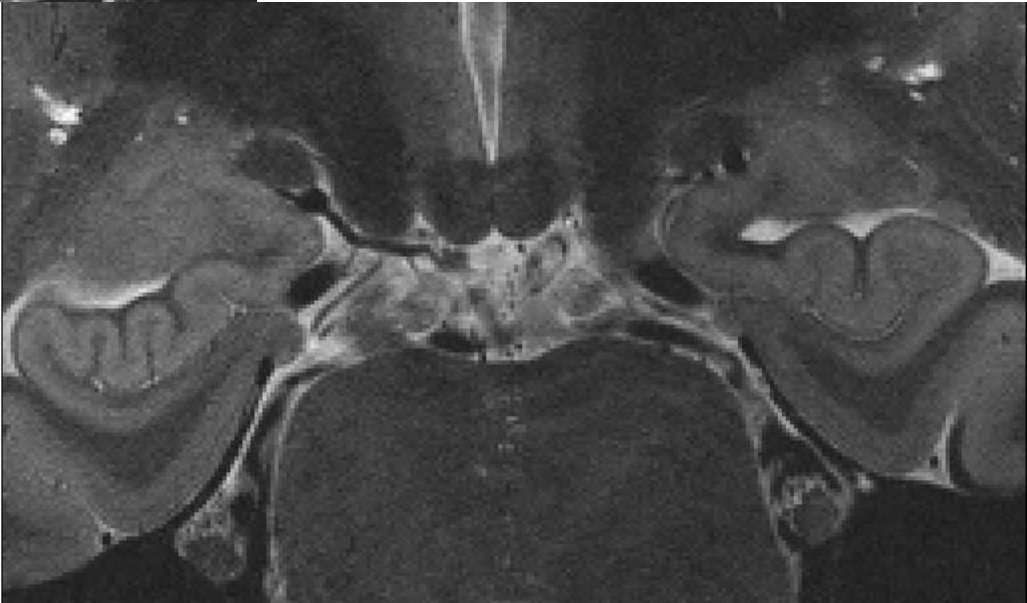
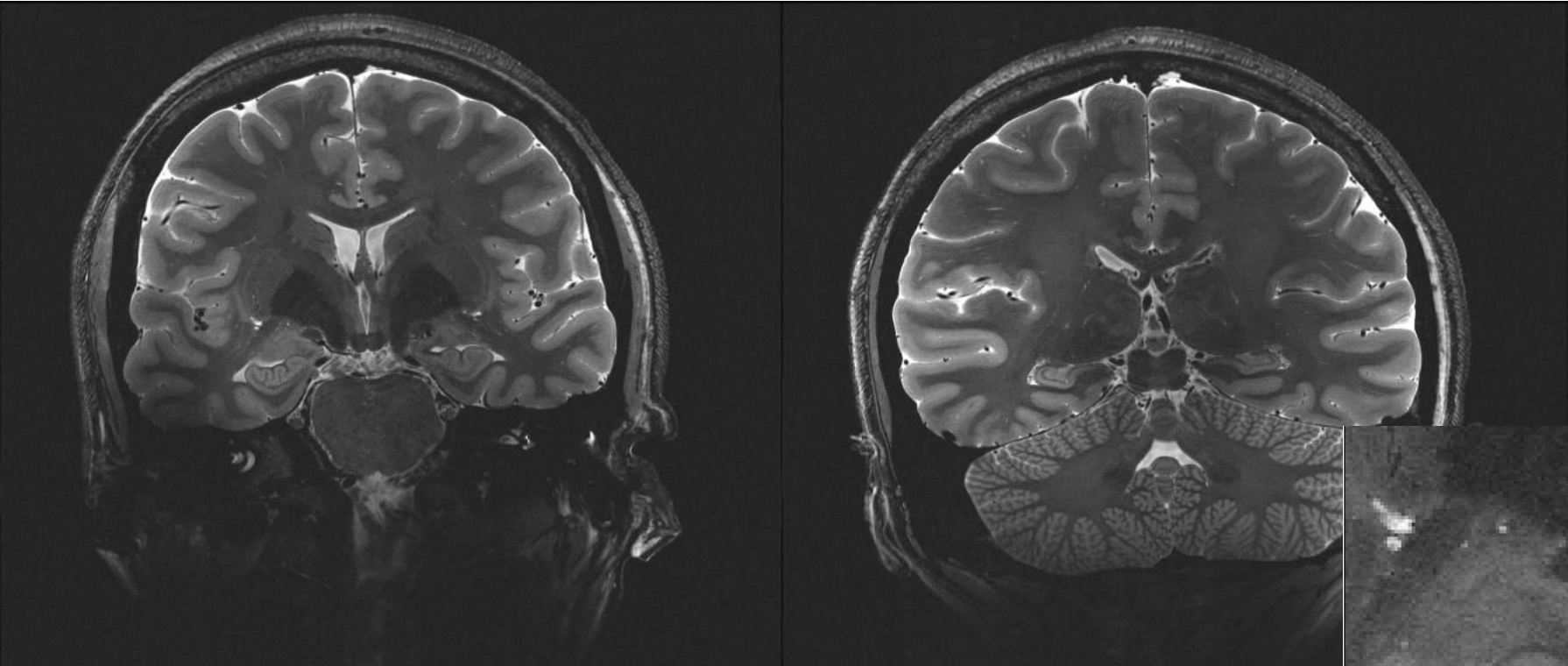
[ID](#) Giske Opheim, [ID](#) Anja van der Kolk, [ID](#) Karin Markenroth Bloch, [ID](#) Albert J. Colon, Kathryn A. Davis, Thomas R. Henry, [ID](#) Jacobus F.A. Jansen, Stephen E. Jones, Jullie W. Pan, Karl Rössler, [ID](#) Joel M. Stein, Maria C. Strandberg, [ID](#) Siegfried Trattng, [ID](#) Pierre-Francois Van de Moortele, [ID](#) Maria Isabel Vargas, Irene Wang, Fabrice Bartolomei, Neda Bernasconi, Andrea Bernasconi, Boris Bernhardt, [ID](#) Isabella Björkman-Burtscher, [ID](#) Mirco Cosottini, Sandhitsu R. Das, [ID](#) Lucie Hertz-Pannier, [ID](#) Sara Inati, [ID](#) Michael T. Jurkiewicz, Ali R. Khan, Shuli Liang, [ID](#) Ruoyun Emily Ma, Srinivasan Mukundan, [ID](#) Heath Pardoe, Lars H. Pinborg, [ID](#) Jonathan R. Polimeni, Jean-Philippe Ranjeva, Esther Steijvers, Steven Stufflebeam, Tim J. Veersema, Alexandre Vignaud, Natalie Voets, Serge Vulliemoz, Christopher J. Wiggins, Rong Xue, Renzo Guerrini, [ID](#) Maxime Guye

21 7T centers with > 2 000 patients  
Indications, patients selection, MRI acquisition, guidelines

# Focal cortical dysplasia

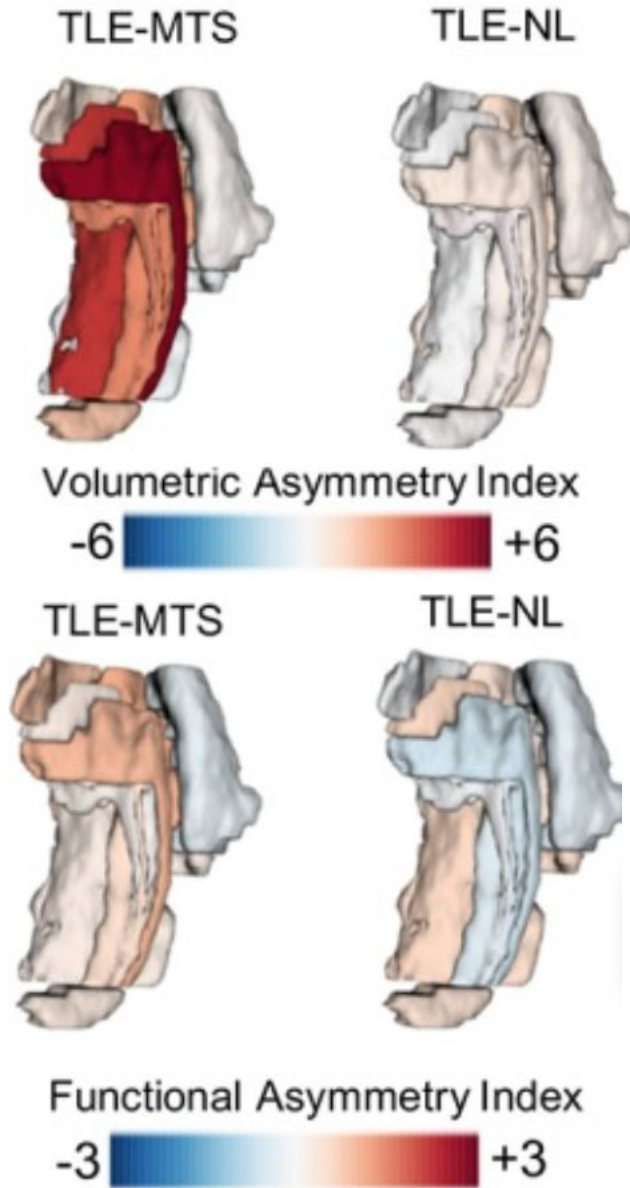
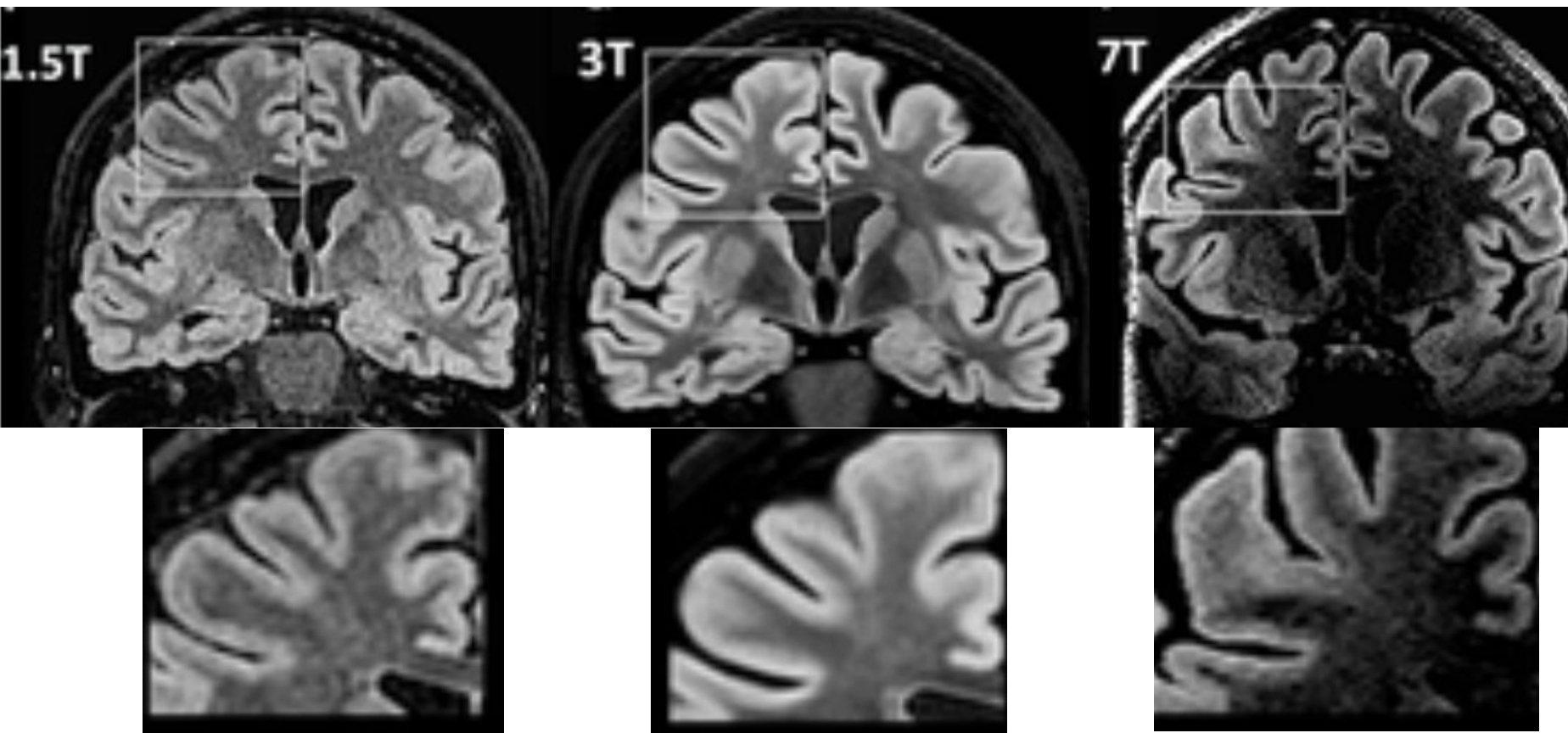


# Hippocampal sclerosis



# 7T MRI

*De Ciantis et al, Epilepsia 2016*



*Shah et al, Hum Brain Map, 2019*

# 7T-MRI and neurological diseases

1- Neurodegenerative disorders

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# MENTAL HEALTH: THE URGENT NEED TO ACT

**Mental health conditions are widespread, undertreated and under-resourced**

## WIDESPREAD

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**1 in 8**

live with a mental health condition

## UNDERTREATED

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**71%**

people with psychosis do not receive mental health services

## UNDER-RESOURCED

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**2%**

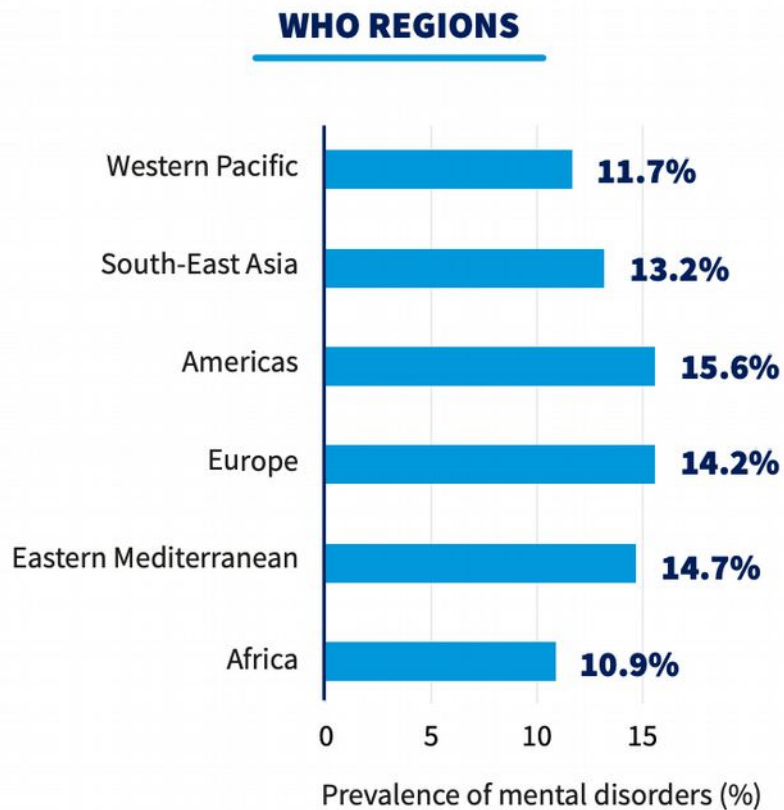
of health budgets, on average, go to mental health

13/03/2023

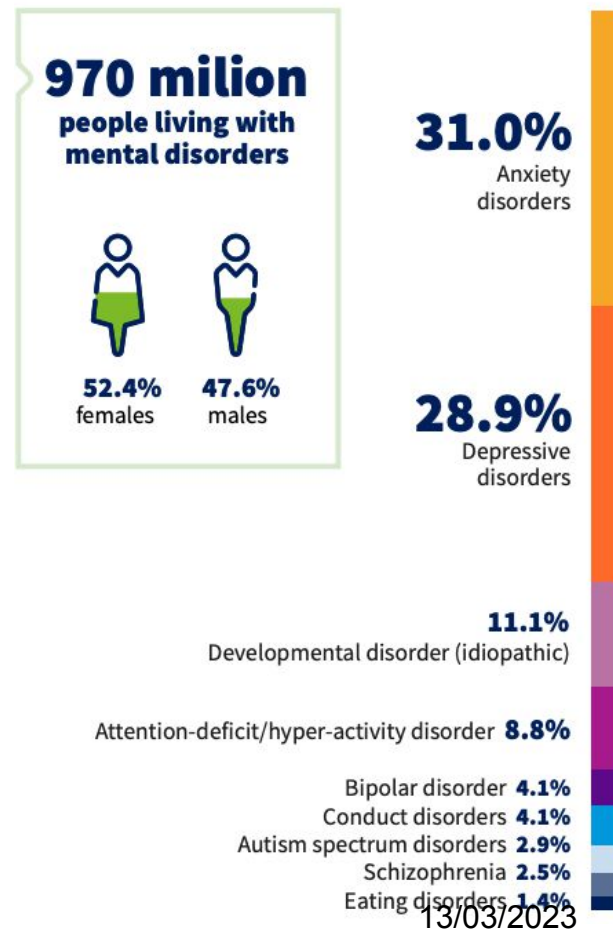
Source: World mental health report, 2022

# MENTAL HEALTH: THE URGENT NEED TO ACT

## Prevalence of mental disorders across WHO regions, 2019

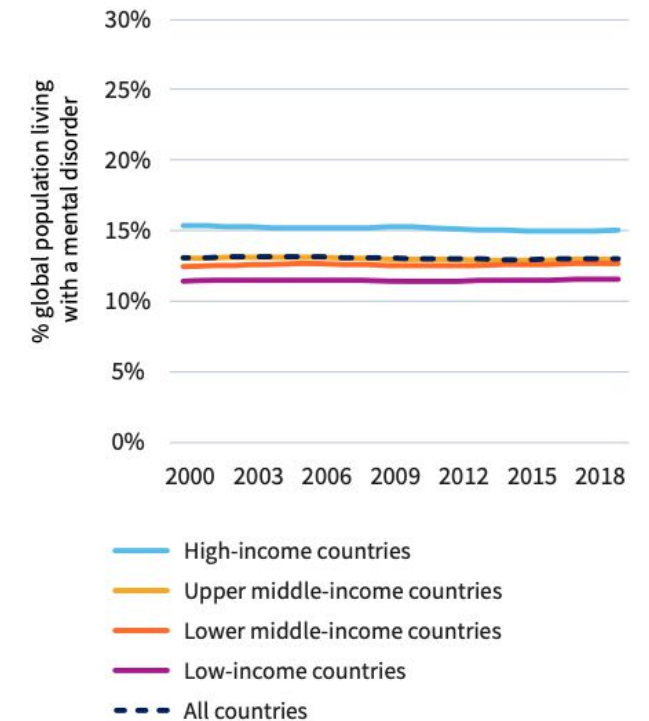


## The global prevalence of mental disorders in 2019

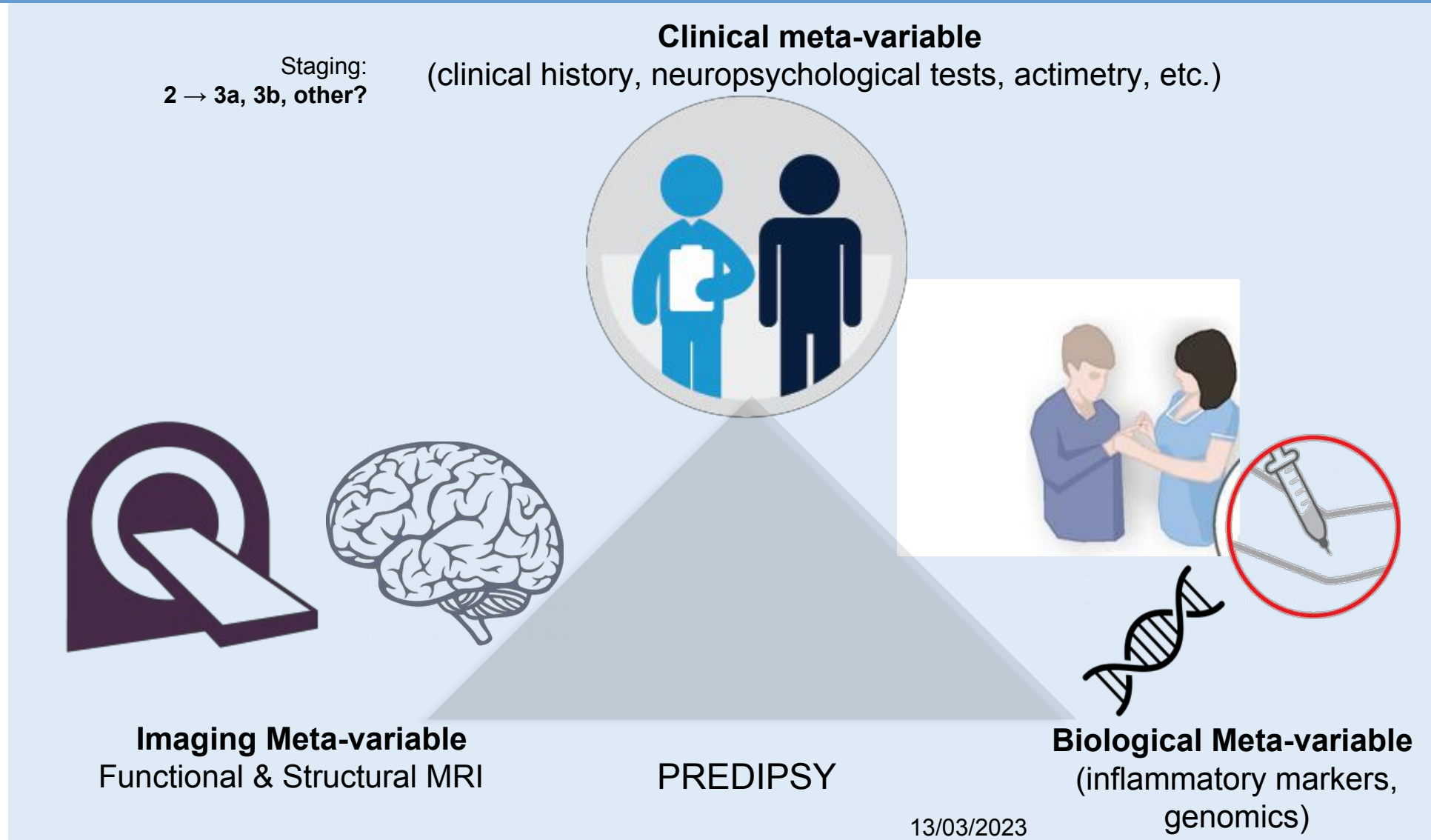


## Dr Nuno Susa: Stress and brain

13% of global population is living with mental disorders



# MENTAL HEALTH: IMAGING AT THE HEART OF THE ACTION



# MENTAL HEALTH: IMAGING AT THE HEART OF THE ACTION

- Decrease the DUP = delay of untreated psychosis
- Rule out any serious neurological disorder
- Give consideration to the patient and his family
- Look for associated pathologies
- Better understand mechanisms: advanced imaging



- Dr Riyad Hanafi: Current applications of MRI in psychotic events

Marshall : « association between DUP and outcome in cohort of PEP

Perkins : « Relation between DUP and outcome : a critical review

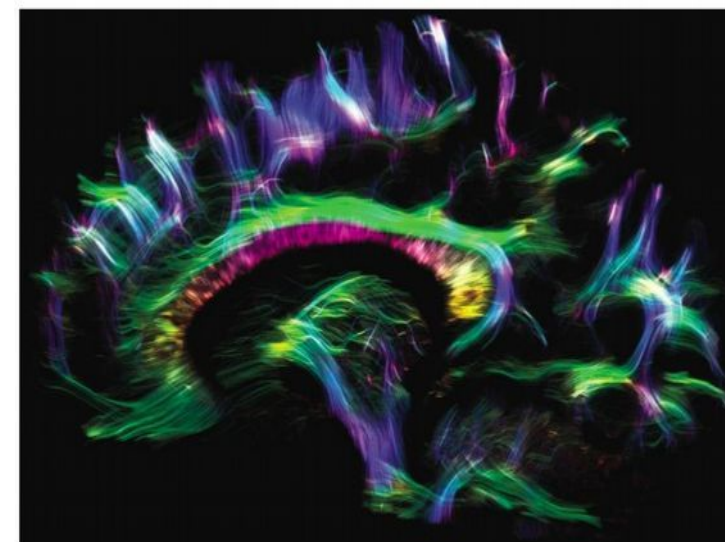
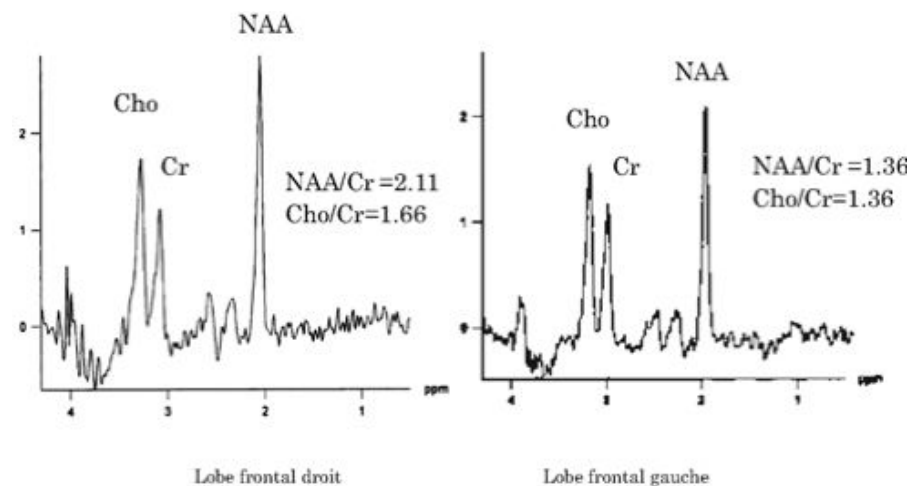
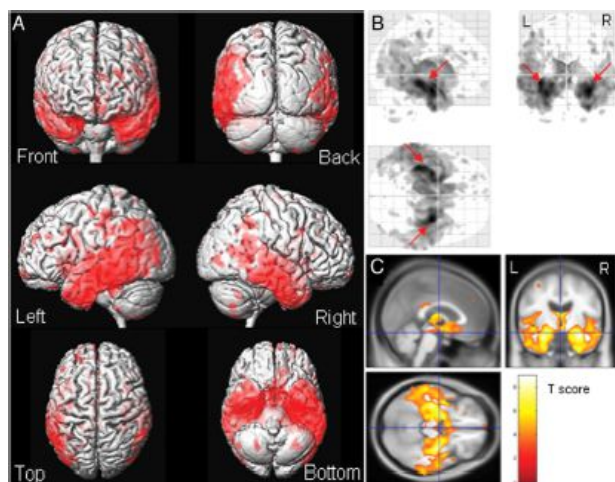
Pentil : « DUP is predictor of long term outcome in schizophrenia : a systematic review.

# BIOMARKERS: PRECISION AND PREDICTION

- Functional MRI : resting state (rs f-MRI)
- MR Spectroscopy
- AI / Machine and Deep learning

**Dr Sidney Krystal: Functional connectivity in bipolar disorders**

**Dr Renaud Lopes: Application of artificial intelligence in normal brain aging**



**FIG 5.** Tractography performed by using diffusion imaging at 7T with readout-segmented EPI and parallel imaging. Image courtesy of Dr Robin Heidemann, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany. Scanner: whole-body 7T MR imaging (Magnetom; Siemens). RF coil: Nova 24-channel head coil. Scan parameters: b-value of 1000 s/mm<sup>2</sup>, resolution = 1 × 1 × 1 mm<sup>3</sup>, 30 diffusion directions, generalized autocalibrating partially parallel acquisition acceleration factor = 3, TE/TR = 60/11,000 ms, scanning time = 75 minutes.

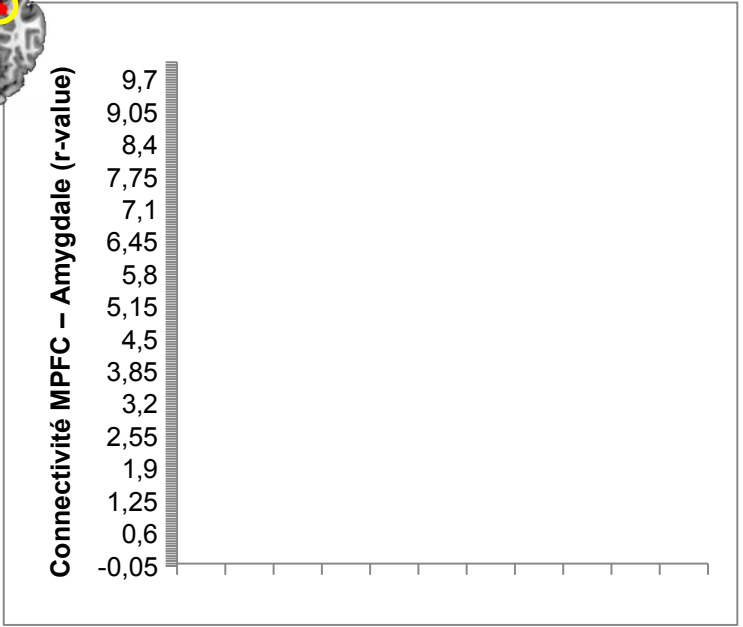
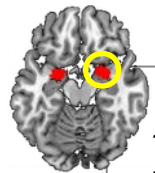
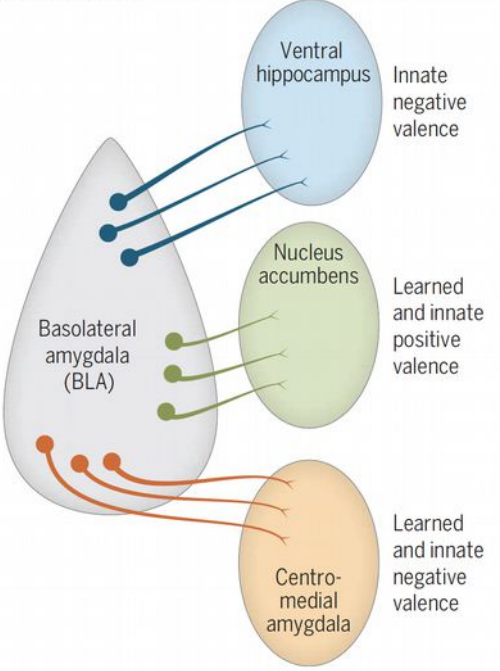
1. Radua et al., meta-analysis : functional and structural cartographies : significant cortical thickness decrease in insular, superior temporal gyrus and anterior cingulum cortex and functional anomalies
2. Brugger et al., NAA decrease in medial temporal lobes and thalamus in schizophrenia.

# Better identification of subcortical nuclei

*Krystal et al, in prog*

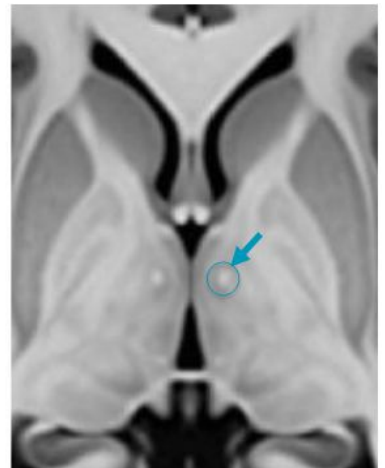
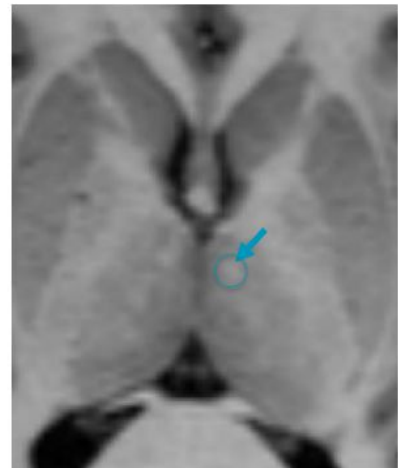
## Valence circuitry

A proposed model for the role of basolateral amygdala projector populations in innate and learned valence

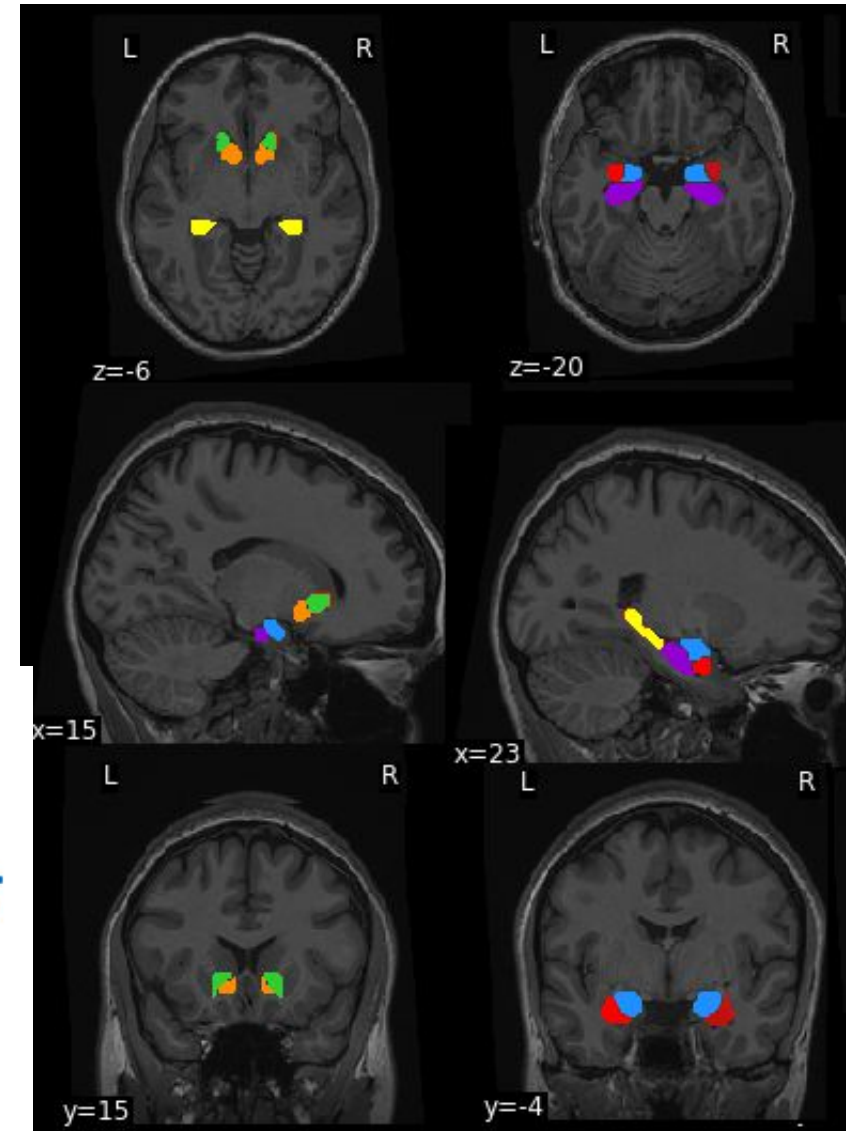


*Favre et al 2014*

**IRM 3T**



**IRM 7T**



*Beyeler et al, 2016*

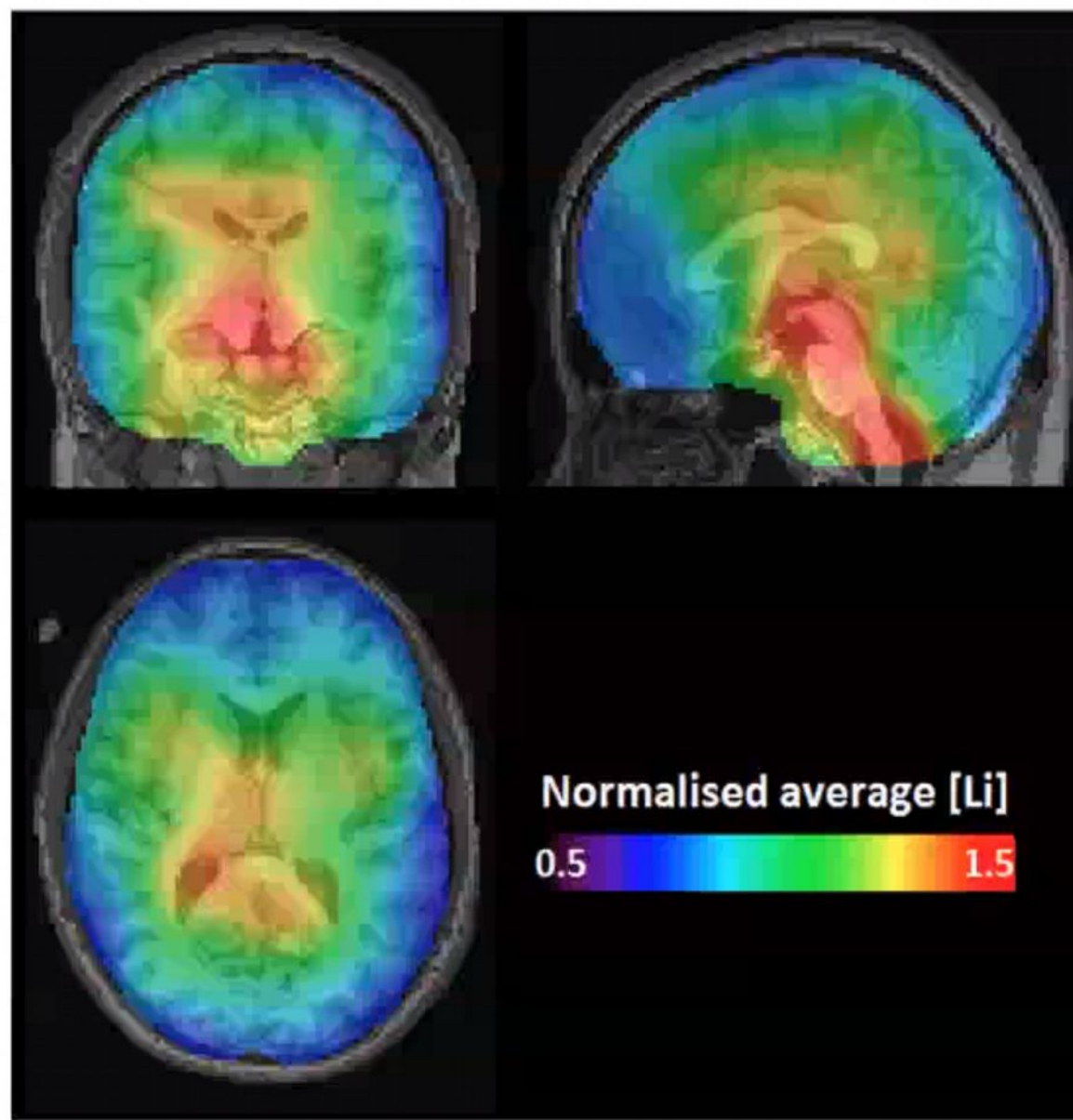
# R-Link: therapeutic response to Lithium & Li spectroscopy

Fawzi Boumezbeur (UNIRS)  
& BD Expert Centers (Widal)

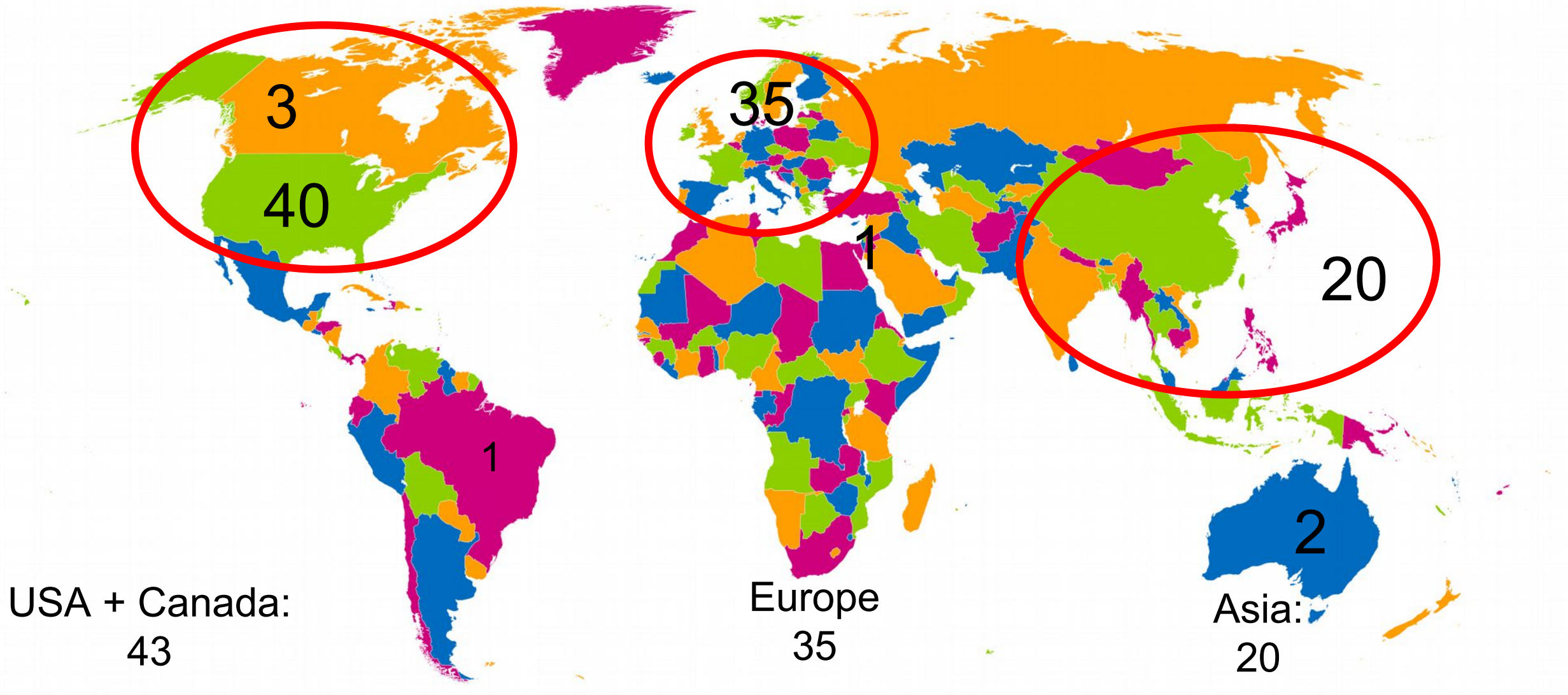
## Objectives

- Studying regional distribution of lithium in treated patients
- Comparing good and poor lithium responders for brain concentration & distribution

Stout, Hozer et al., Biological Psychiatry, 2020



# 102 7T MRIs worldwide





# Regional project « ARIANES »





Association pour la Recherche en Imagerie Avancée  
en Neurosciences Et Santé mentale

***arianes.fr***

ETAT DES LIEUX

La région Hauts-de-France est l'une des plus denses en termes de population et des plus défavorisées en termes de santé. Une immense partie de la population souffrant de pathologies neurologiques et psychiatriques n'est pas suivie dans des centres experts.

LA NEUROIMAGERIE A REVOLUTIONNE LA PRISE EN CHARGE.

Cependant, l'accès reste limité et inégalitaire. Les bilans ne sont pas harmonisés et ne s'échangent pas entre les différents acteurs de la région. Il n'y a donc pas de cohérence en termes de soins, de formation et de recherche entre les différents acteurs. De nombreuses avancées pré-cliniques et cliniques récentes (télé-AVC, imagerie interventionnelle, Sclérose en plaques) et à venir (Parkinson, Alzheimer, épilepsie, post AVC, neuro-oncologie, dépression, schizophrénie...) pourraient profondément améliorer la prise en charge de ces patients.

# ÉTAT DES LIEUX

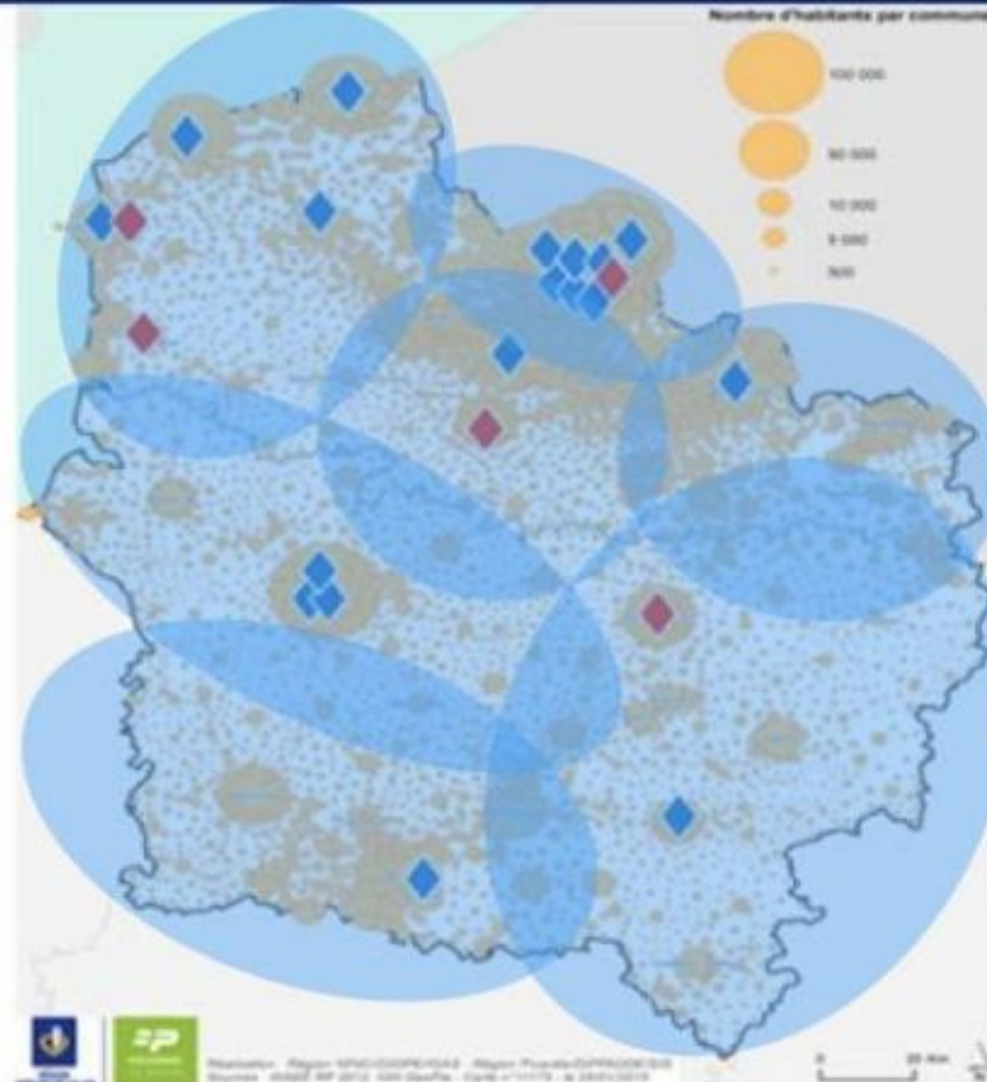
## Une Région dense...

6 millions d'habitants  
189 hab. / km<sup>2</sup>

3<sup>ème</sup> Région fr. en pop.  
2<sup>ème</sup> Région fr. en densité

## ... et des disparités

- Fusion (2016)
- Métropole lilloise
- **7 territoires**



## L'existant en imagerie

Un maillage potentiel de  
114 IRM et 132 scanners

Dont 33 IRM 3 Tesla ◆ et 10  
en installation ◆

## Les établissements de santé

2 CHU à Lille et Amiens  
50 hôpitaux  
80 cliniques

## OBJECTIFS STRATEGIQUES

- 1- Faire des Hauts-de-France un pôle de référence au nord de l'Europe en imagerie des neurosciences et santé mentale.
- 2- Maintenir des équipes soignantes de proximité et de qualité sur tout le territoire
- 3- Nouveau modèle médico-économique intégrant les trois composantes : - recherche - formation initiale et continue - soins pertinents 24h/24 en santé neurologique et mentale avec une dimension territoriale pour répondre aux défis immenses du futur.

## **OBJECTIFS OPERATIONNELS**

Création d'une infrastructure innovante de RECHERCHE CLINIQUE grâce au MAILLAGE des équipements IRM, pour les neurosciences et la psychiatrie en Hauts-de-France.

Valorisation des COHORTES de patients avec HARMONISATION DES PROTOCOLES en recherche et en clinique.

Amélioration de l'ACCÈS et de la PERTINENCE DES SOINS, encore augmentés par la téléexpertise et l'e-learning.

Acquisition d'une IRM 7T permettant la découverte de nouveaux biomarqueurs, et à partir de laquelle les 24 IRM 3T pourront être optimisées grâce à l'Intelligence Artificielle.

# 7T MRI project: A project for patient care

## Existing networks in neurosciences and psychiatry

- PSYMAC
- TELE-AVC
- MEOTIS (memory centers)
- PARCSEP (Parkinson's disease, Multiple sclerosis)
  - Neurooncology
  - Epilepsy
  - Neuropediatrics



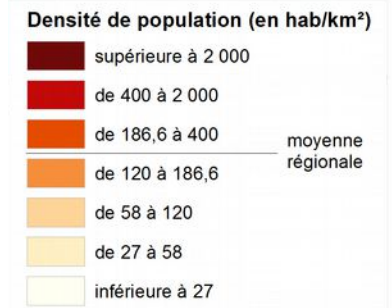
# Hauts-de-France

Nord Pas-de-Calais Picardie



# IRM

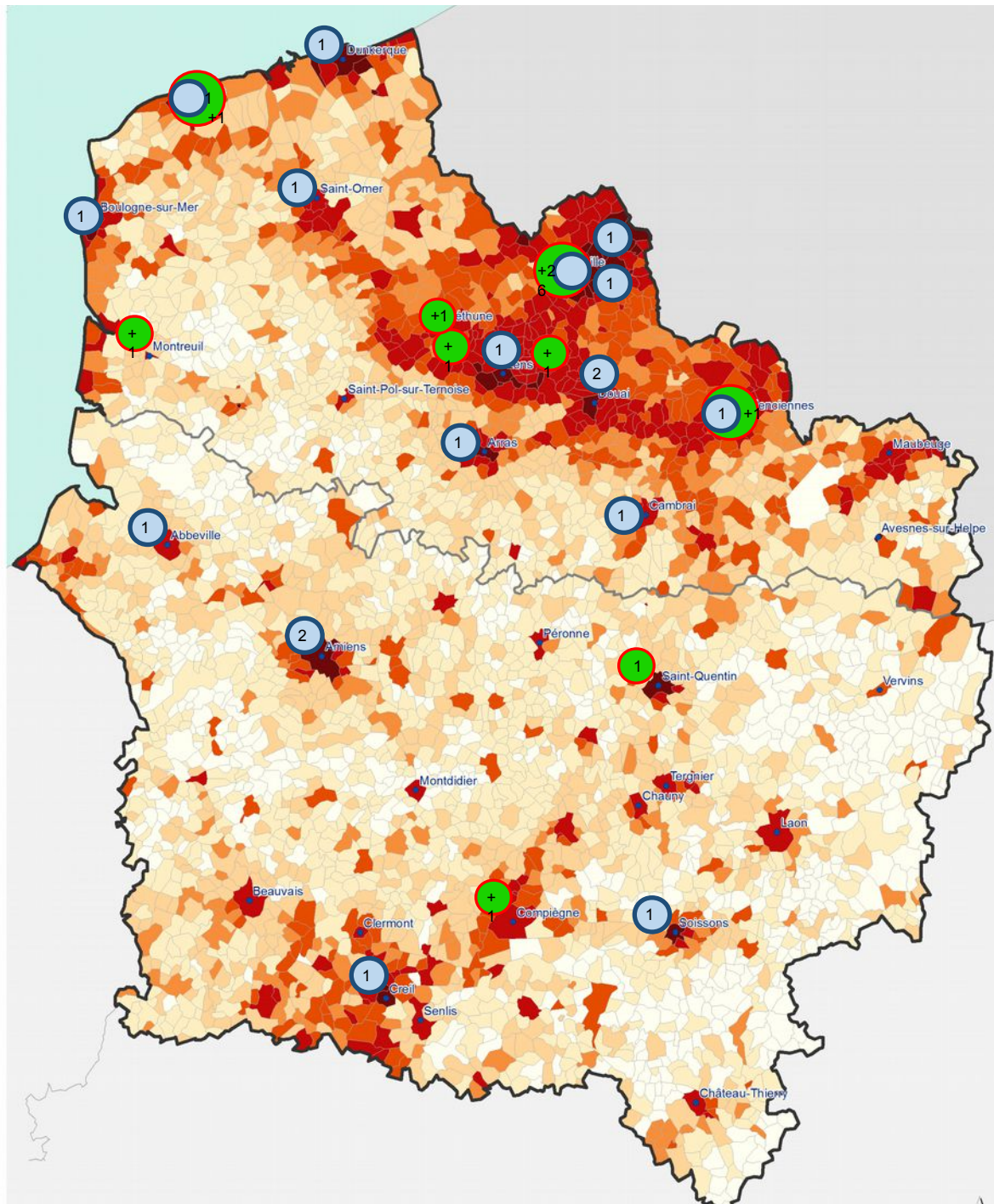
Densité de population en 2012



IRM 3T en fonction

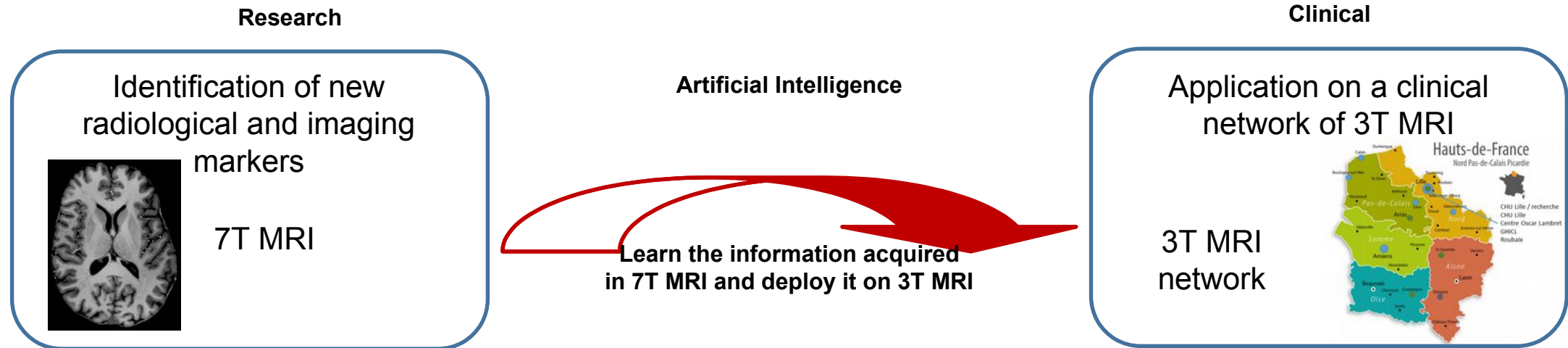


IRM 3T autorisée

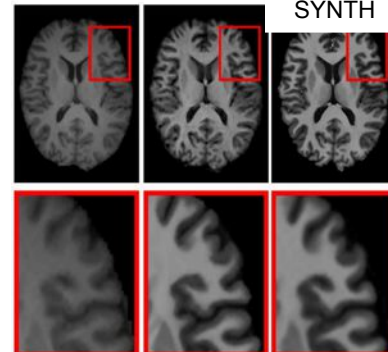


2024 : Lille University Hospital will acquire an ultra-high-field MRI (7T) dedicated to Human.

The use of 7T MRI in research cohorts will allow the identification of new radiological and imaging markers in neurological and psychiatric diseases.



3T MRI    7T MRI    7T SYNTH



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# Innovations en Imagerie Médicale

## ARIANES Hauts-de-France



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