APPLICATION OF 7T MRI IN NEURORADIOLOGY

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OUTLINE

- I. IRM 7T : Overview
- II. Clinical applications in neuro-vascular diseases
- III. Clinical applications in neuro-inflammatory diseases
- IV. Clinical applications in mental health
- V. Clinical applications in neuro-degenerative diseases
- VI. Regional project « ARIANES »

7T MRI

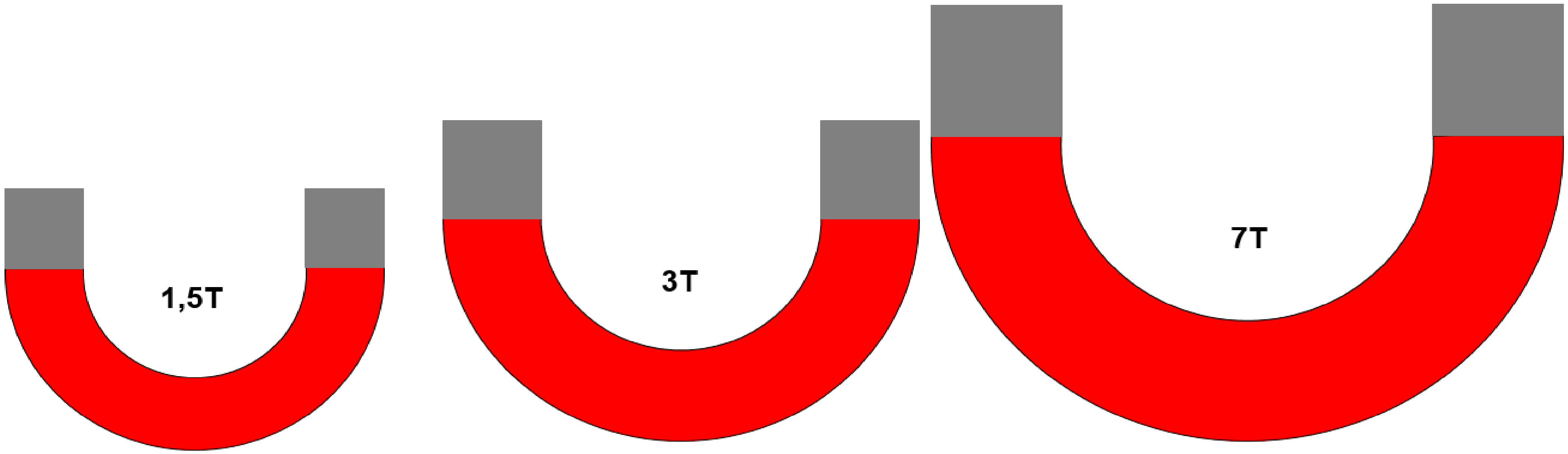
- Increase in B0
- Increased proton resonance frequency -> need to increase RF wave power

  → more energy delivery (measured in W/kg) / heating of local tissues

  → difficulty in homogeneizing B0 & B1+ / image inhomogeneity

Modification in T1 and T2 relaxation times

- Improved signal/noise ratio (SNR)



Improved spatial resolution

7T vs 3T

	Advantages	Disadvantages
Specific absorption rate		Increase in energy delivery
T1	TOF, ASL, Lesser gadolinium need	Increase acquisition time
T2		Diffusion
T2*	SWI, BOLD	
SNR (signal/noise ratio)	Improved spatial resolution	
Chemical shift	Improved fat saturation Improved spatial resolution	Increase in chemical shift
Magnetic susceptibility	SWI, BOLD	Increase in susceptibility artifact
Dielectric effect		Variable signal loss

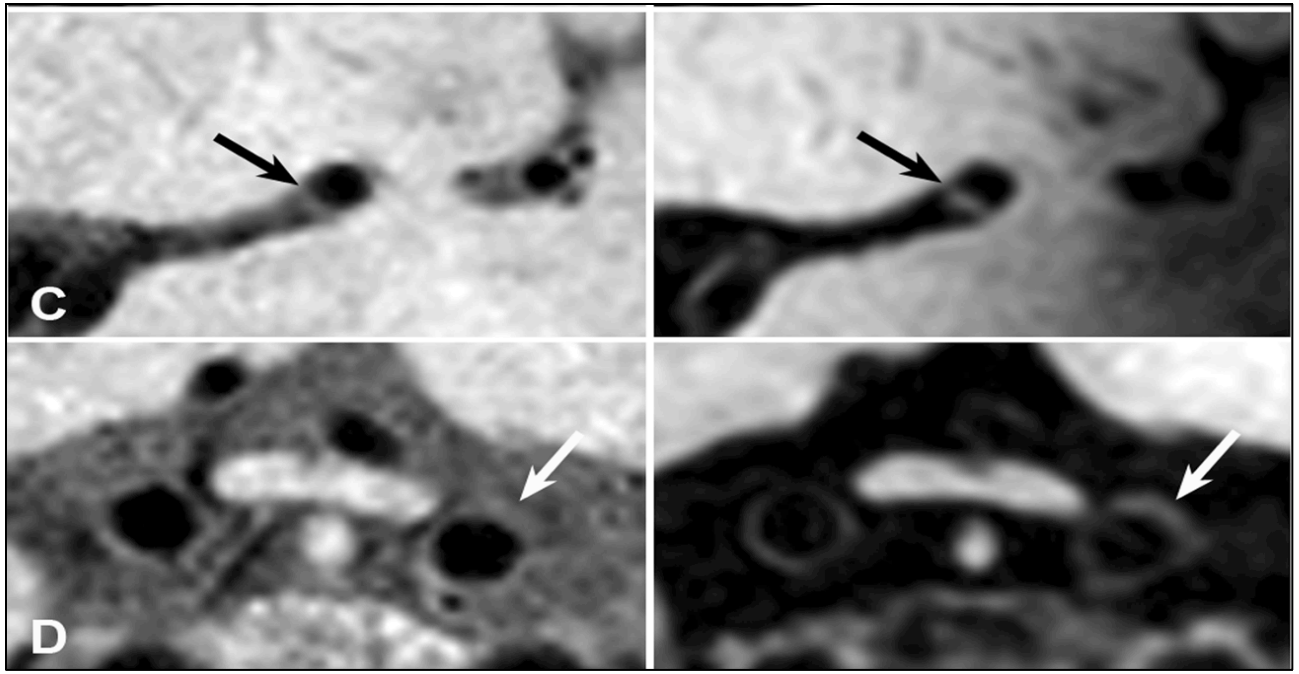
II . CLINICAL APPLICATIONS OF 7T MRI IN NEURO-VASCULAR DISEASES

Currently no application in stroke to guide thrombolysis or thrombectomy.

Application in the workup of stroke :

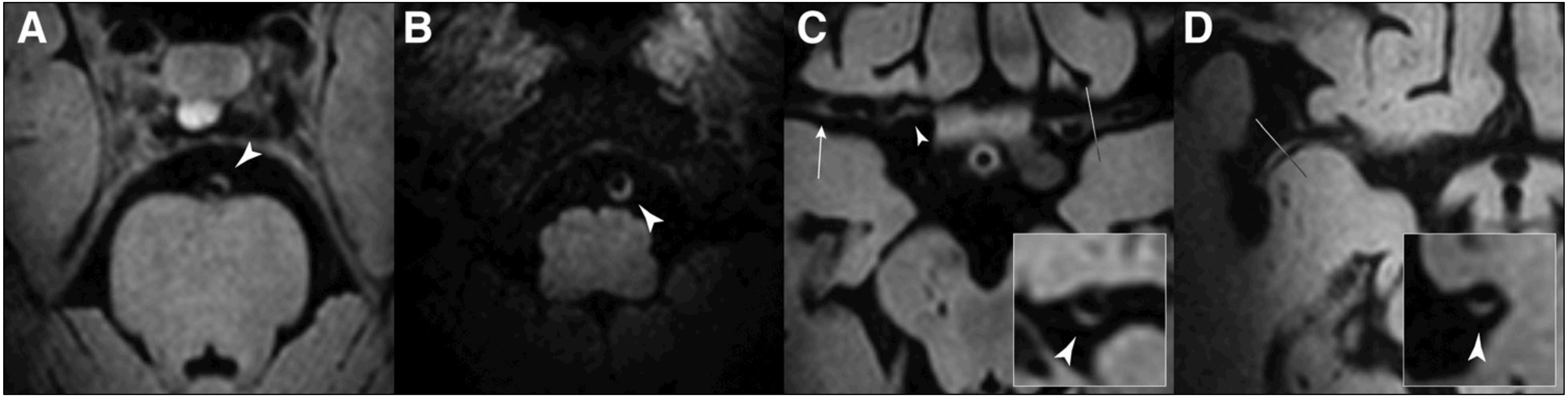
- intra-cranial atheromatous disease

Better definition of lesion load on 7T MRI in asymptomatic elderly patients



Harteveled et al 2017

→ 7T MRI helps separate out risk factors from wall abnormalities in circle of Willis arteries.



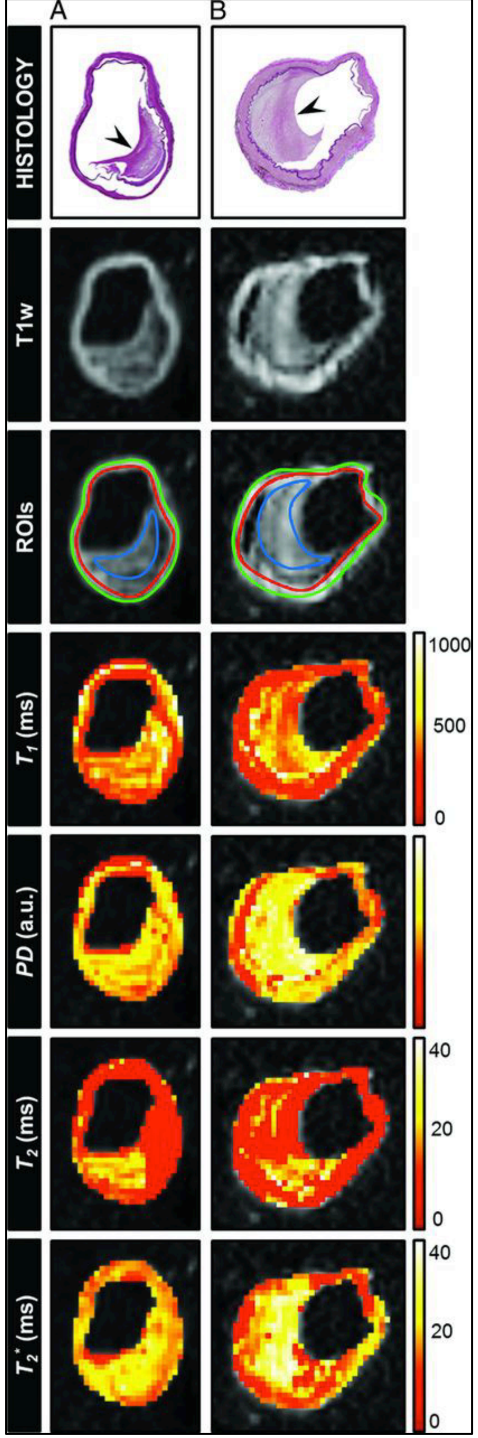
Zwartbol et al 2019

Significantly more lesions in elderly, hypertensive, type 2 diabetes
→ Change in treatment plan in risk factors in symptomatic patients with no other cause for stroke ?

Future goal: *in vivo* study of plaque composition, possible *ex vivo* with sequences not available for clinical use.

→ Differentiate between plaque components based on T1 shortening value.

Harteveled et al 2016

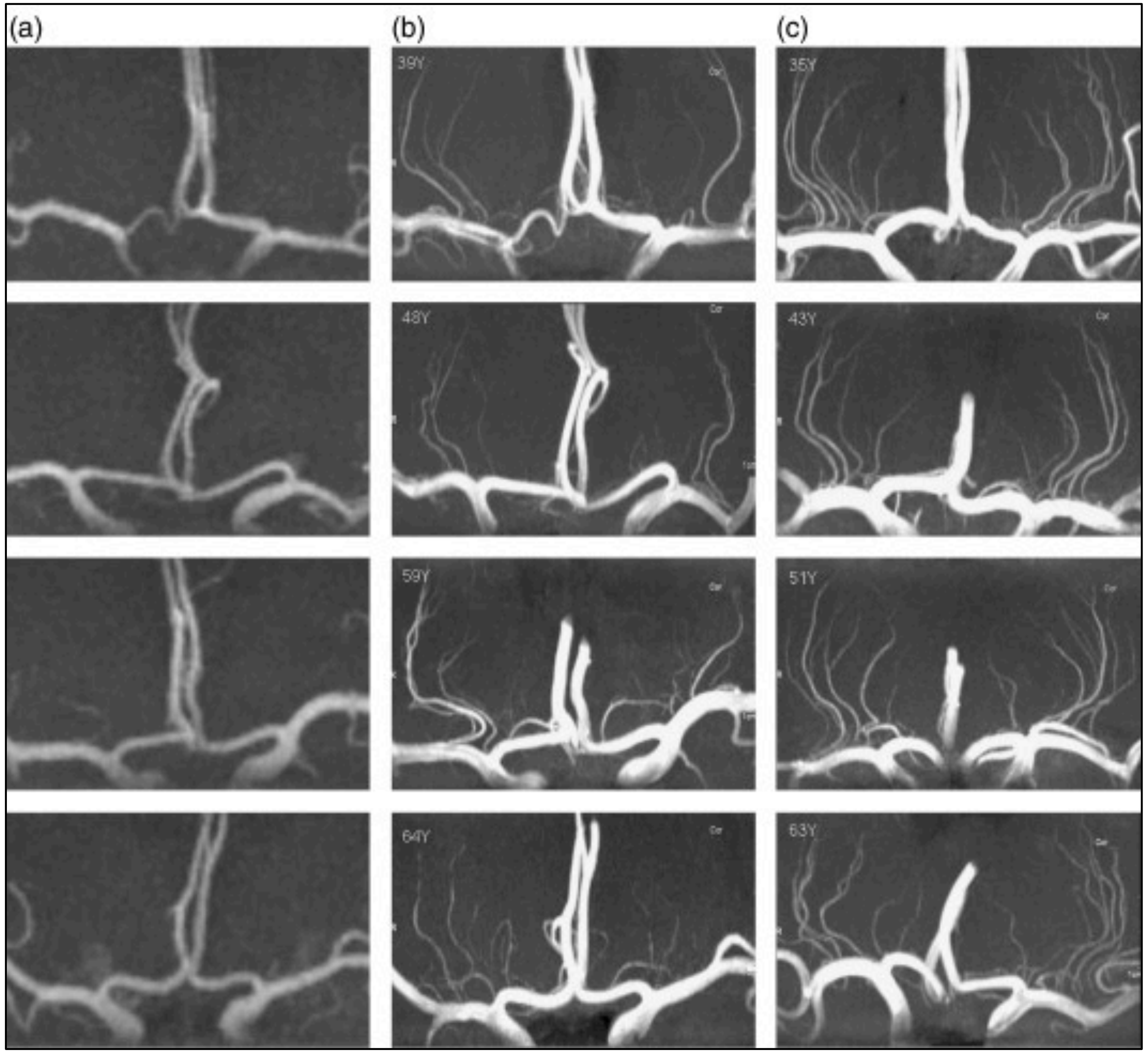


Stroke workup :

- intra-cranial atheromatous disease

- Small artery disease (lipohyalinosis)

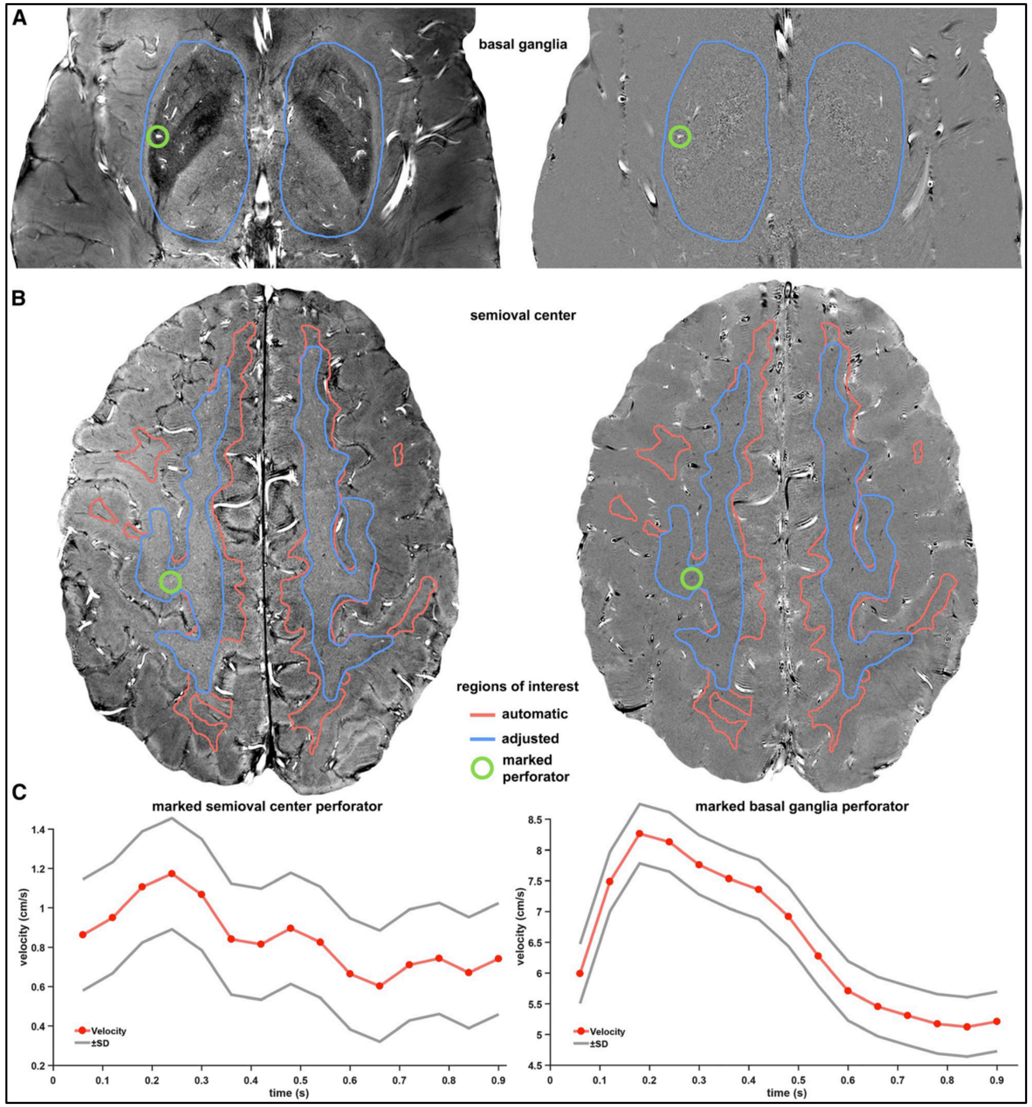
Better morphological definition of lenticulo-striate arteries (lacunar strokes).



Decrease in number of lenticulo-striate arteries

Kang et al 2010

Also functional evaluation of perforating arteries. Physiopathological confirmation.



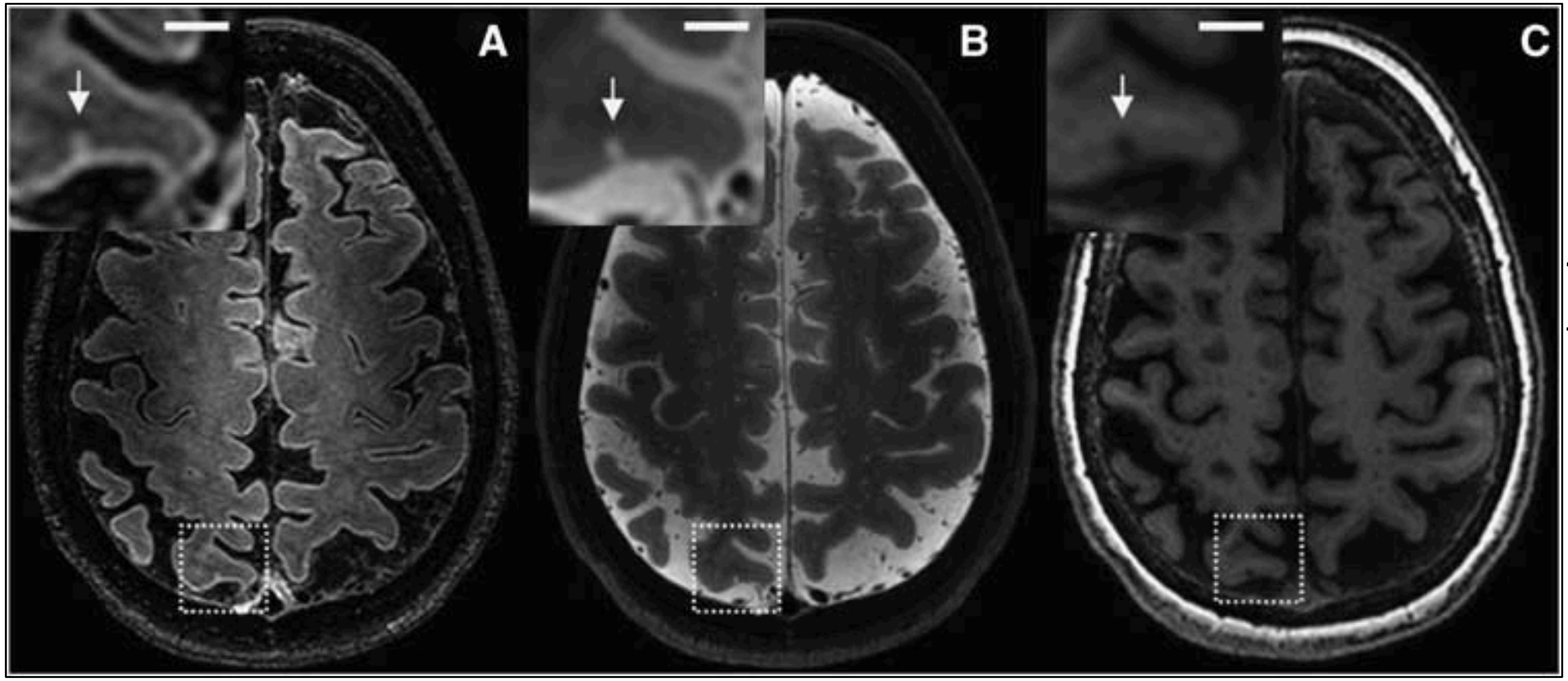
Higher pulsatility index in patients compared to controls.

Geurts et al 2019

Currently no application in stroke to guide thrombolysis or thrombectomy.

Application in stroke workup.

Biomarkers for neurodegenerative disease (especially vascular démentia).



Detection of cortical micro-infarcts or chronic microbleeds. Topography can suggest type of dementia.

Van Veluw et al 2013

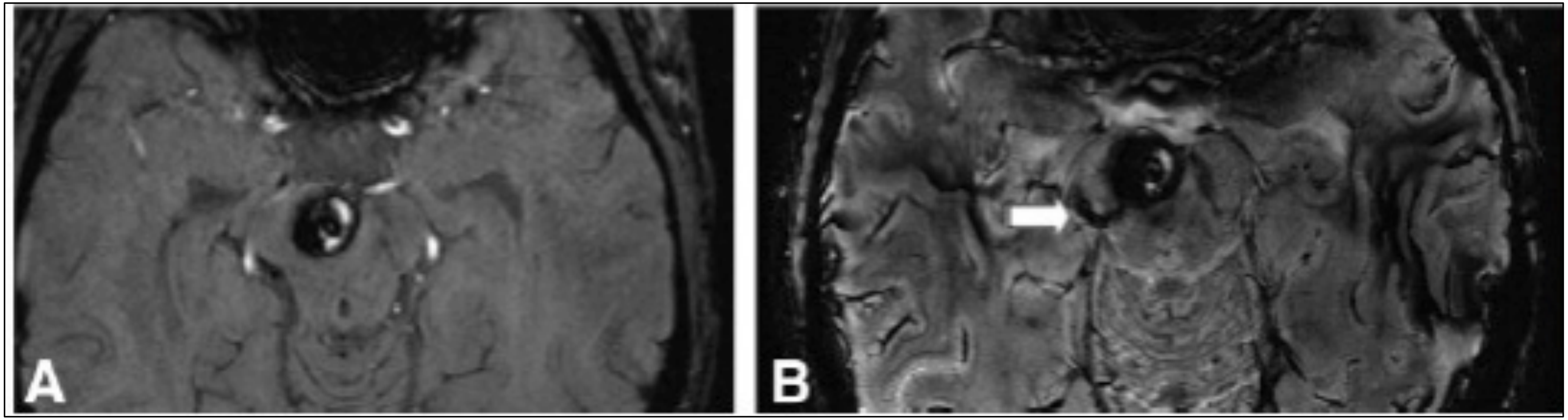
Currently no application in stroke to guide thrombolysis or thrombectomy.

Application in stroke workup.

Biomarkers for neurodegenerative disease (especially vascular démentia).

Improved detection of cavernomas (type IV) and draining vein.

Improved magnetic susceptibility leading to improved detection of hemorrage, particularly in cavernomas.



Frischer et al 2012

Currently no application in stroke to guide thrombolysis or thrombectomy.

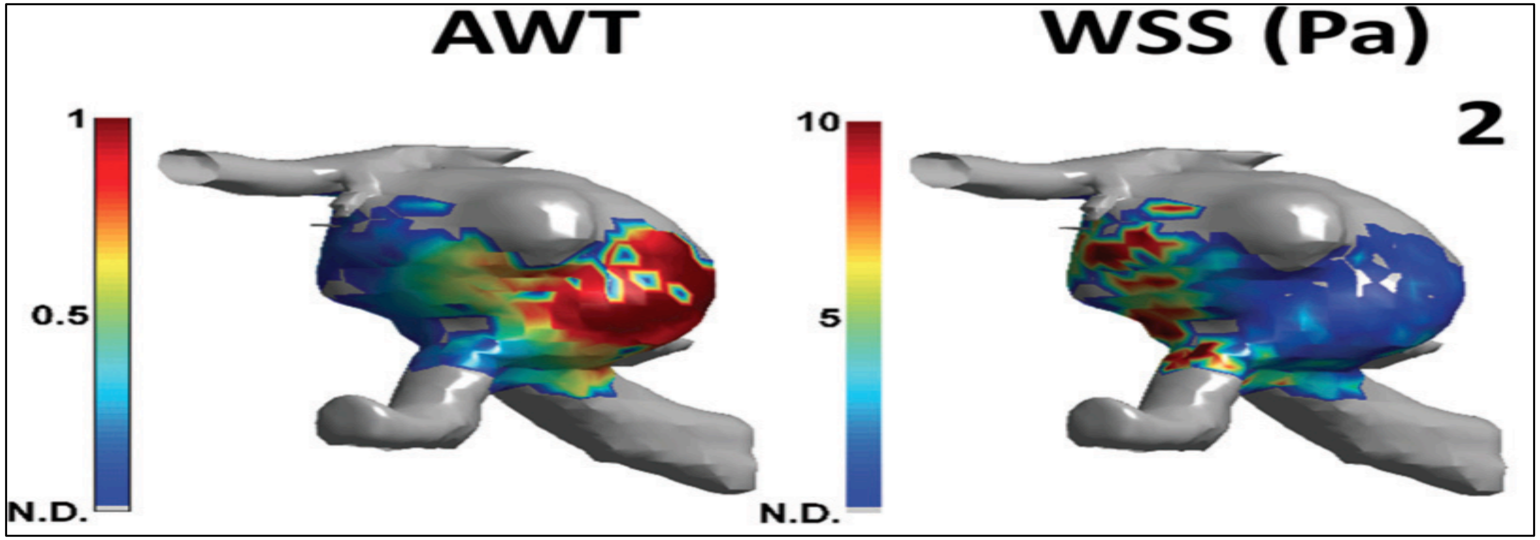
Application in stroke workup.

Biomarkers for neurodegenerative disease (especially vascular démentia).

Improved detection of cavernomas (type IV) and draining vein.

Unruptured cerebral aneurysms

Development of technique which has allowed to show inverse correlation between unruptured aneurysm wall thickness and friction strain on vessel wall.



Blankena et al 2016

Important for the study of pathological mechanisms leading to aneurysm growth and rupture -> prediction of rupture risk.

Currently no application in stroke to guide thrombolysis or thrombectomy.

Application in stroke workup.

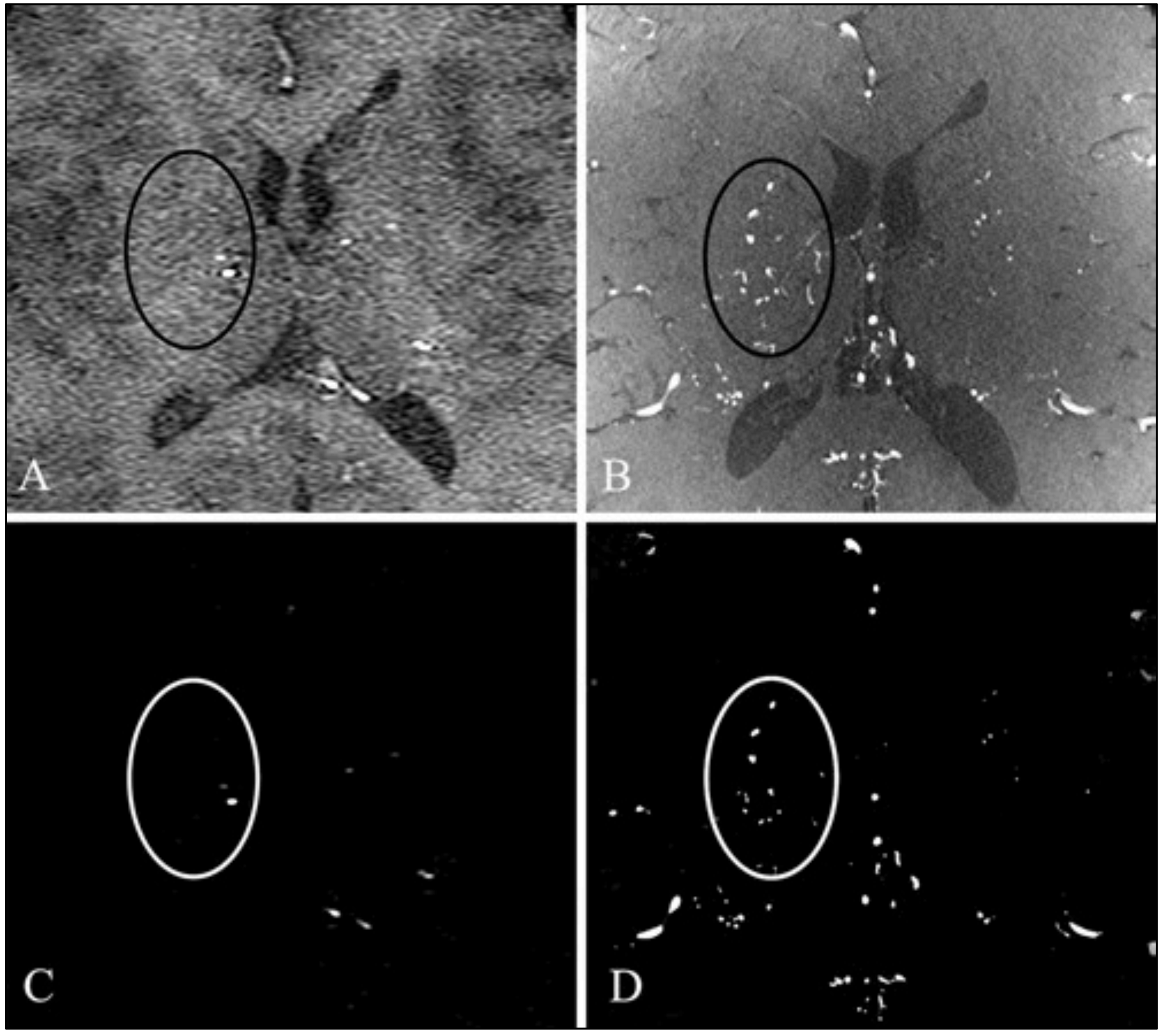
Biomarkers for neurodegenerative disease (especially vascular démentia).

Improved detection of cavernomas (type IV) and draining vein.

Unruptured cerebral aneurysms

Replacement for DSA (Digital Subtraction Angiography).

7T MRI could replace DSA for the diagnosis/followup of certain diseases, i.e. Moya-Moya disease or syndrome in pediatric population.



Current diagnostic criteria suggest that arterial stenosis/occlusion + abnormal arteriolar network are sufficient for diagnosis.

Deng et al 2016

III . CLINICAL APPLICATIONS OF 7T MRI IN NEURO-INFLAMMATORY DISEASES

Multiple Sclerosis

Demyelinating disease

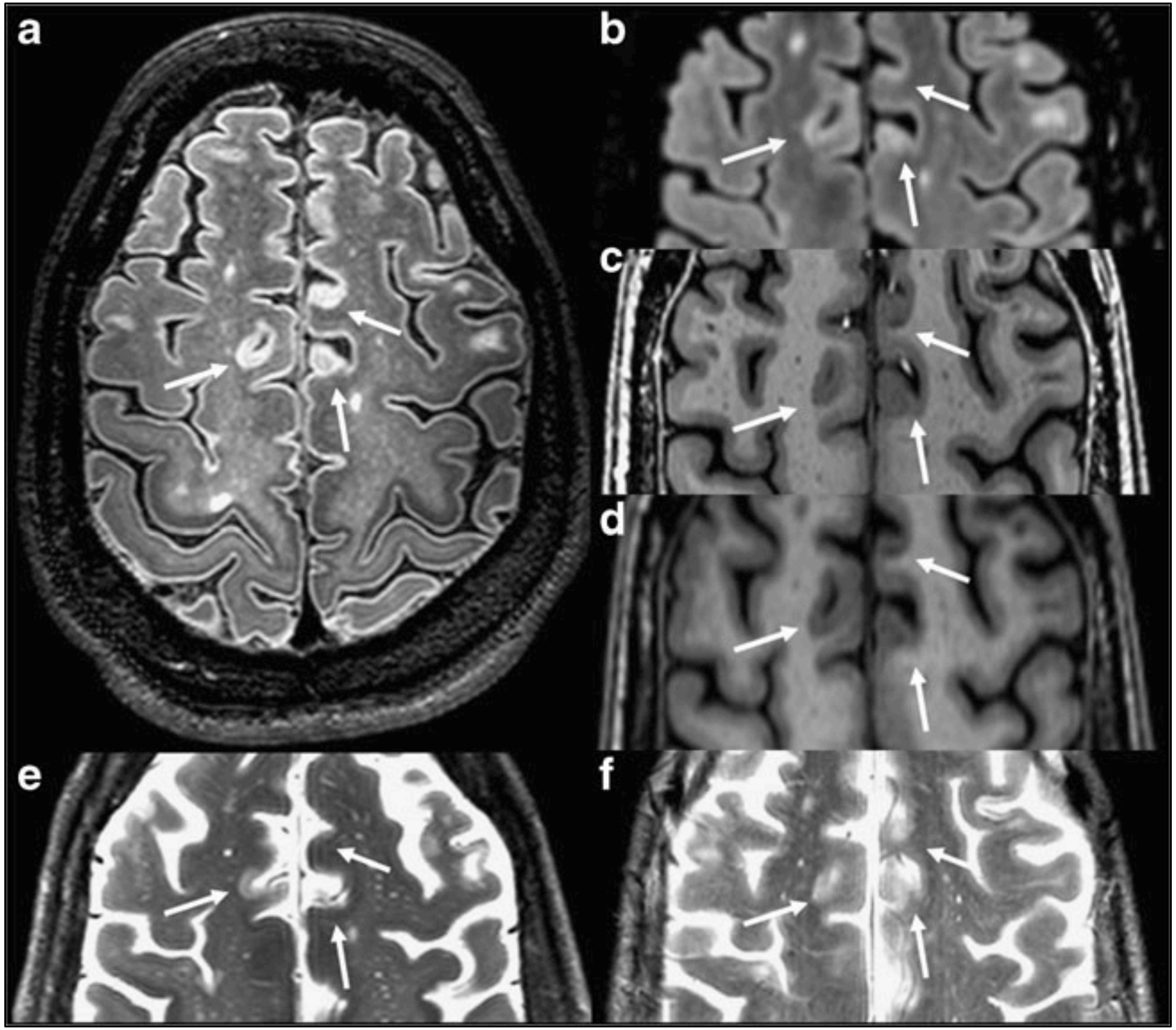
Hyperintense T2-FLAIR lesions

MRI : diagnosis / followup / prognosis

& rule out differential diagnoses (NMO +++)

Recently introduced in criteria for spatial dissemination: **cortical lesions**.

→ augment diagnostic specificity for MS

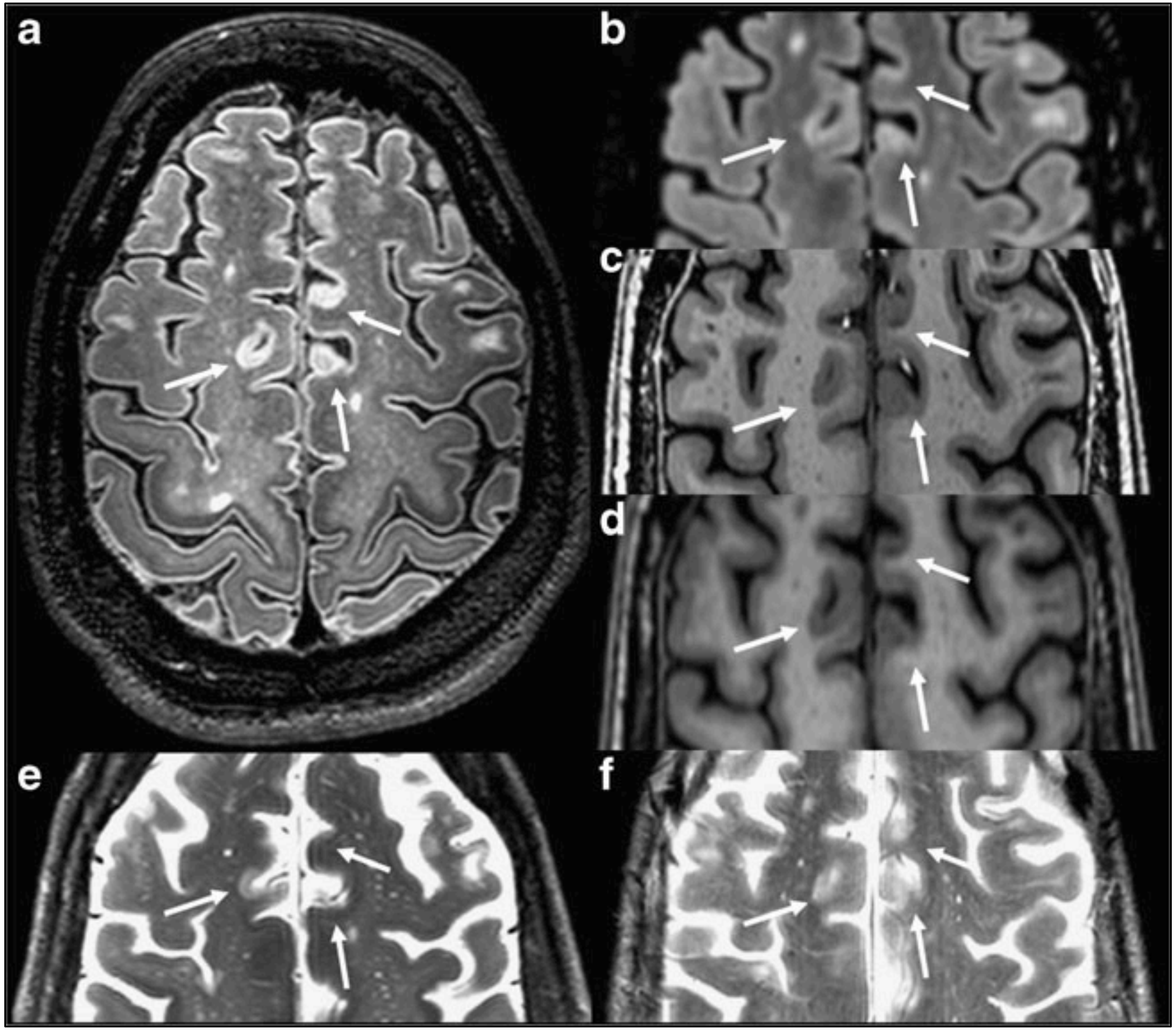


De Graaf et al 2013

Recently introduced in criteria for spatial dissemination: **cortical lesions**.

→ augment diagnostic specificity for MS

→ more gray matter lesions detected on 7T MRI (Kollia et al 2009, De Graaf et al 2013, Kilsdonk et al 2016)



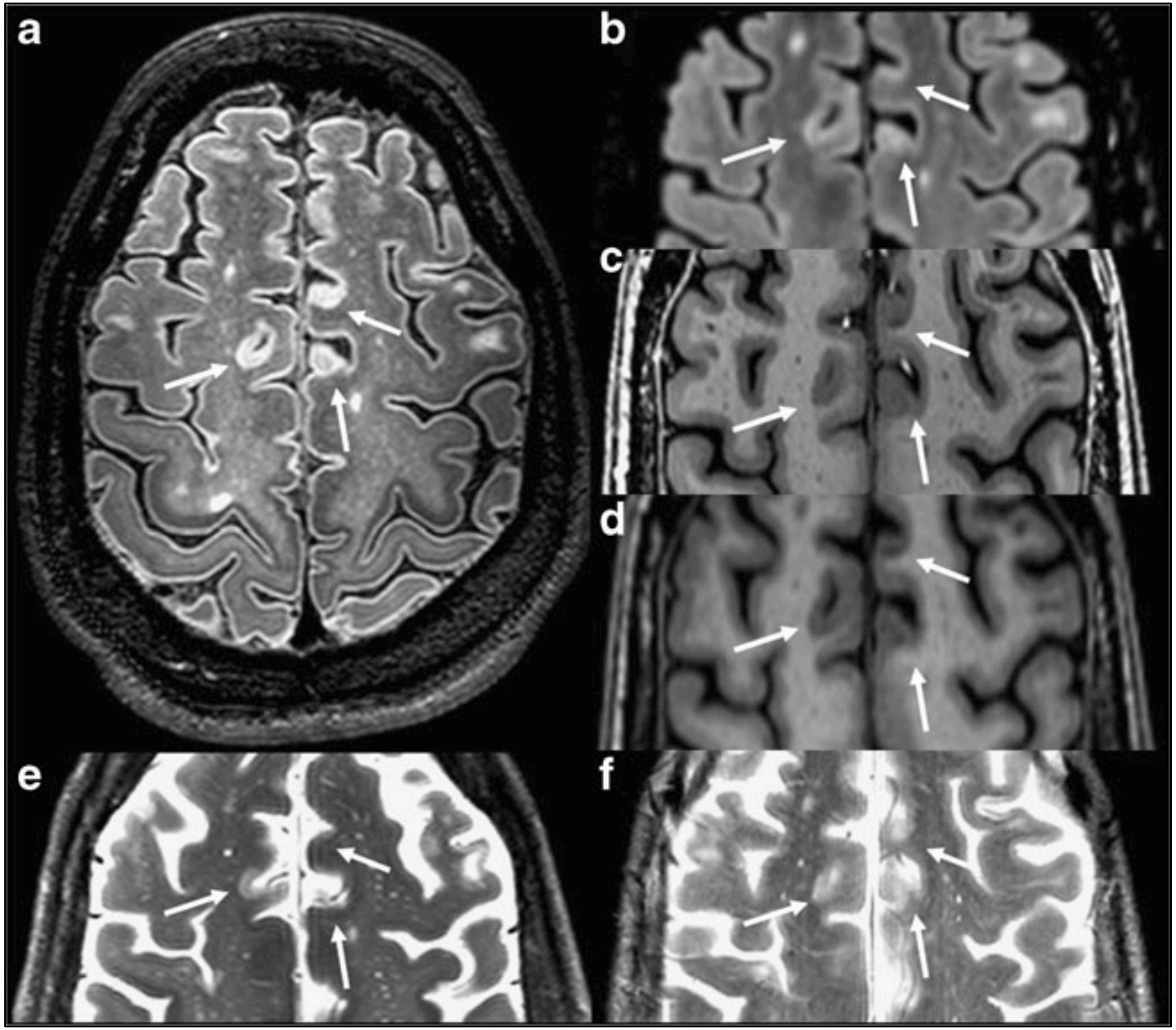
De Graaf et al 2013

Recently introduced in criteria for spatial dissemination: **cortical lesions**.

→ augment diagnostic specificity for MS

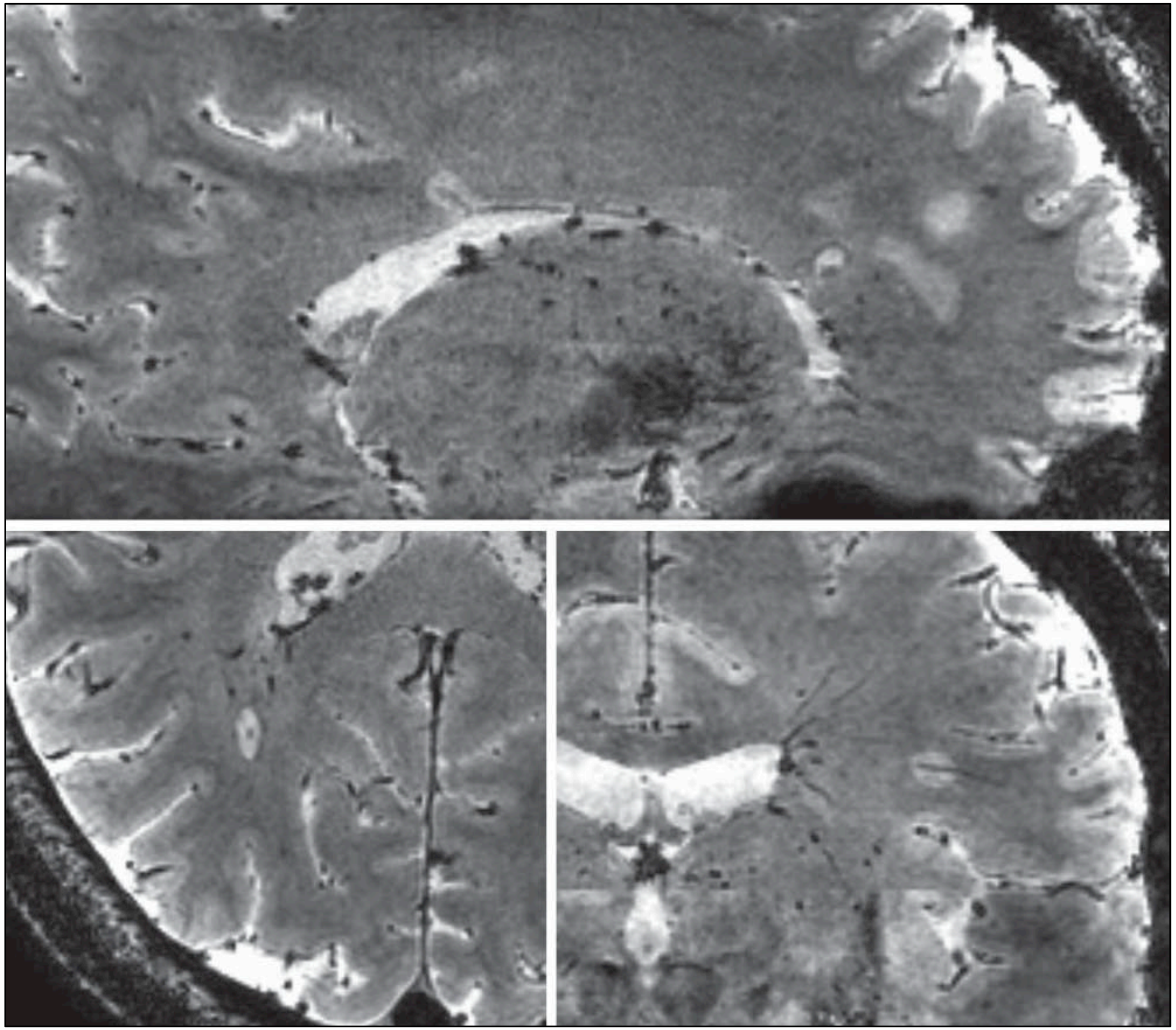
→ more gray matter lesions detected on 7T MRI (Kollia et al 2009, De Graaf et al 2013, Kilsdonk et al 2016)

→ strong association with physical and mental disability (Harisson et al 2015)



De Graaf et al 2013

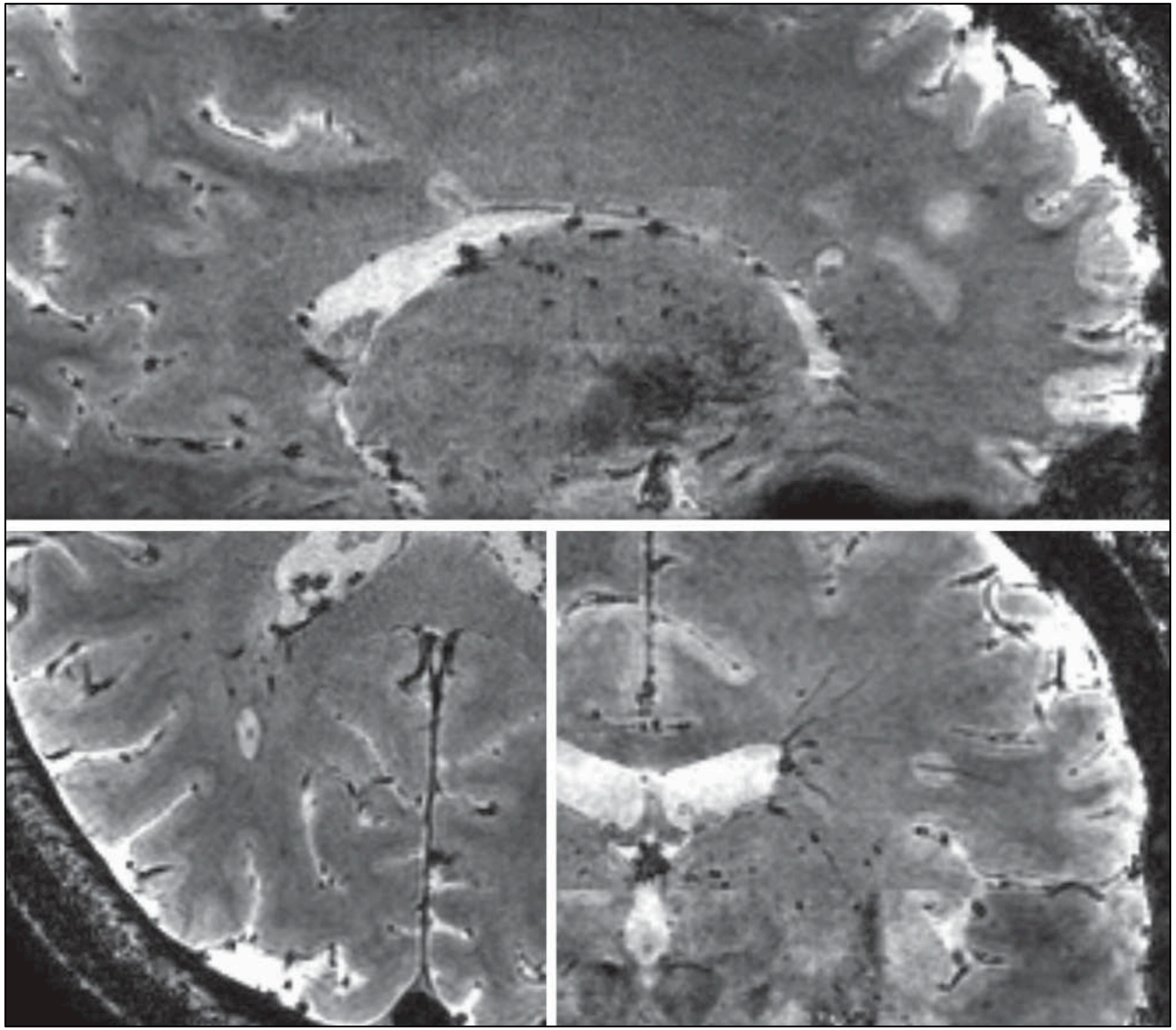
Central Vein sign recently described in MS diagnostic criteria.



Mistry et al 2013

Central Vein sign recently described in MS diagnostic criteria.

More frequently seen on 7T MRI compared to 3T (Tallantyre et al 2009)



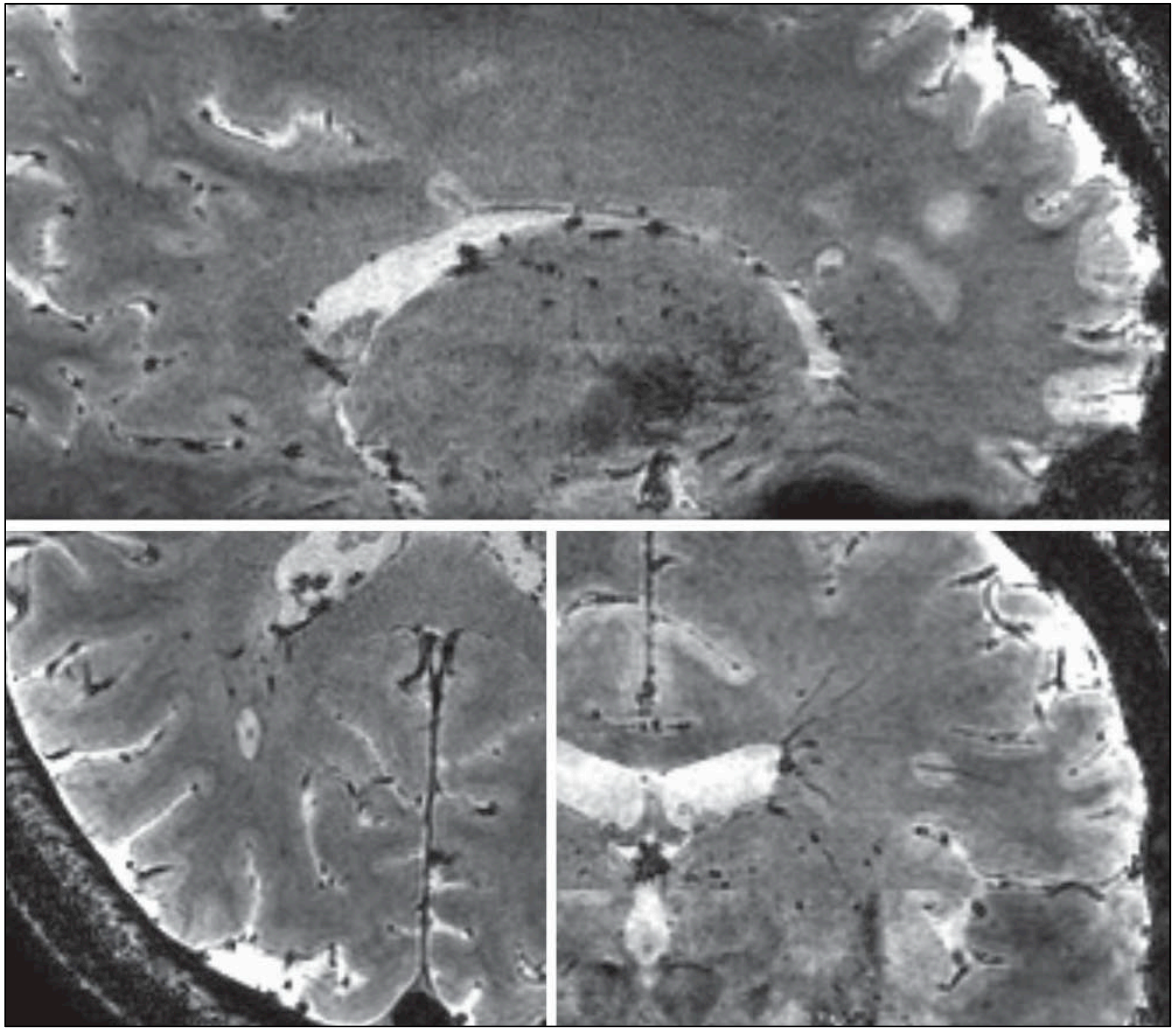
Mistry et al 2013

Cut-off in >40% lesions in T2 hypersignal with **central vein** diagnostic characterization of MS.

→ vs vascular hypersignal vasculaires
(Kilsdonk et al 2014)

→ vs hypersignal in NMO
(Sinnecker et al 2012)

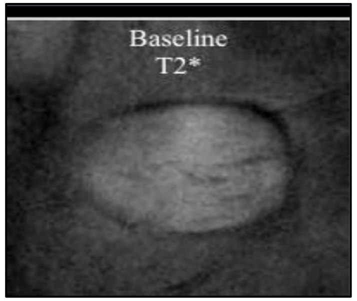
→ vs hypersignal in Susac disease
(Wuerfel et al 2012)



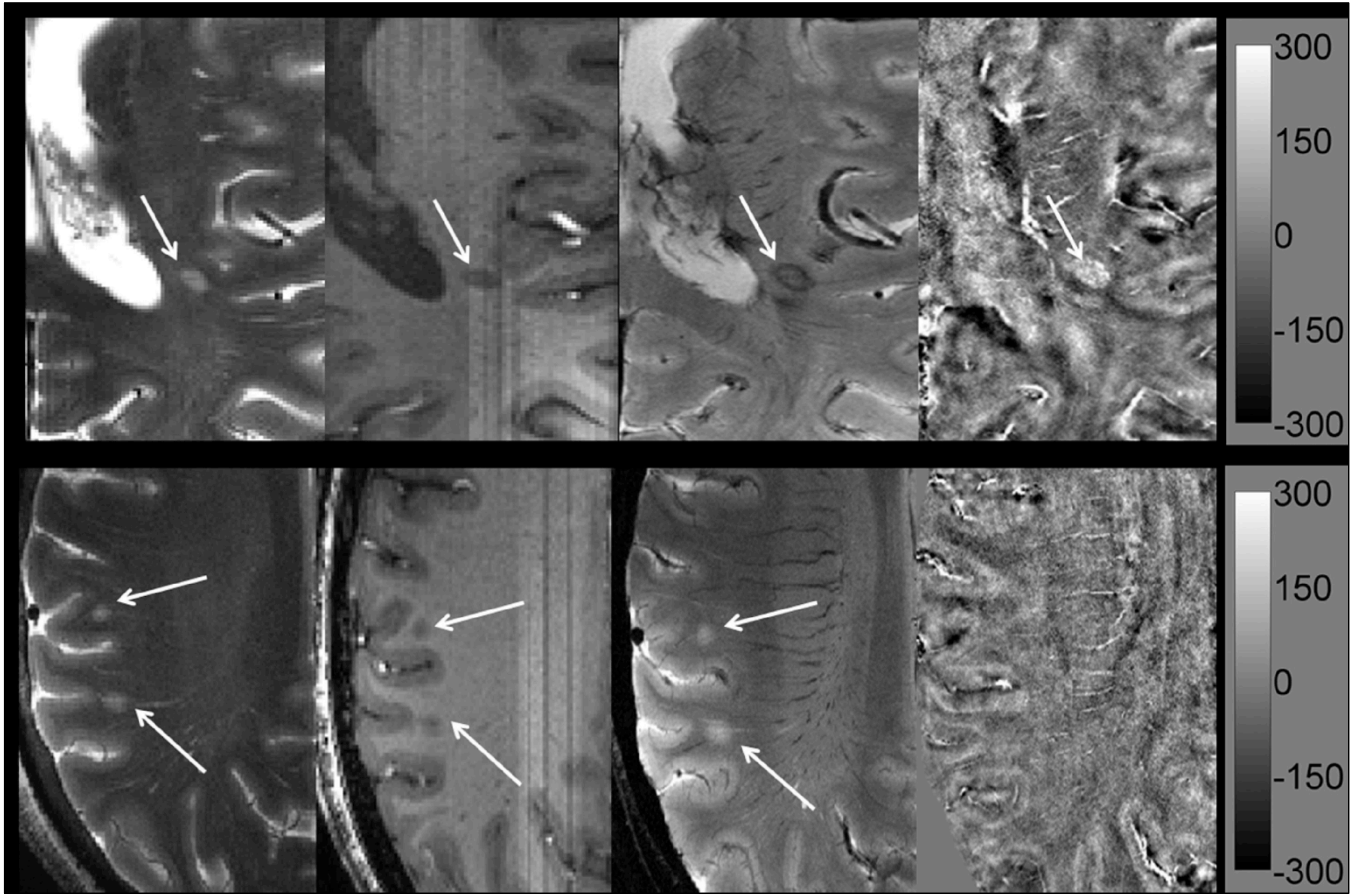
Mistry et al 2013

Paramagnetic ring sign

→ vs NMO
(Chawla et al 2016,
Sinnecker et al 2016)



Absinta et al 2013



Chawla et al 2016

Central vein sign

+ **Paramagnetic ring sign**

+ **Cortical lesions** (recently introduced criterion, but categorized as juxta-cortical lesions)

= MRI Biomarkers for MS

More conspicuous on 7T MRI

Significantly helps rule out differential diagnoses (ECTRIMS 2019 - Stockholm)

IV. CLINICAL APPLICATIONS OF 7T MRI IN MENTAL HEALTH

High prevalence

3rd most common pathology after cancer and cardio-vascular diseases (WHO)
1 in 5 French citizen has mental health disease (Institut Montaigne)

Economic burden

Direct and indirect costs estimated at 110 Billion Euros in France
Only 2% of biomedical expenditures in France (21 million Euros – Institut Montaigne)

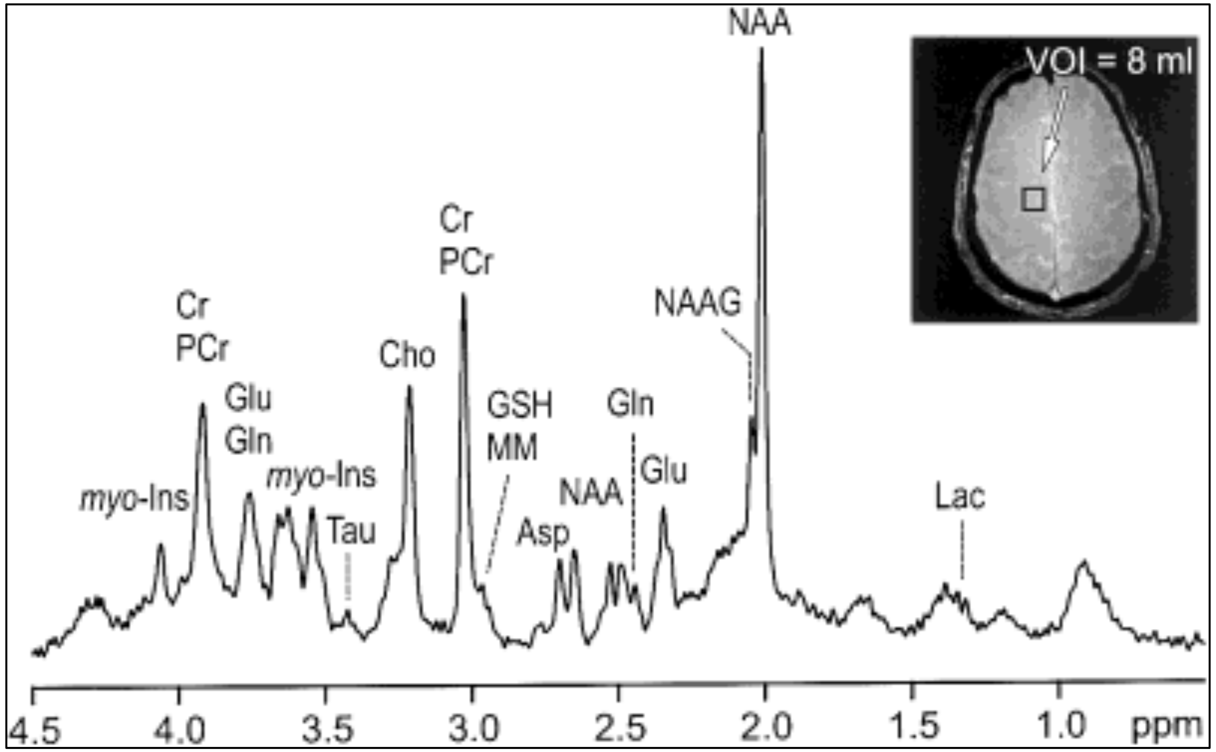
Few or no biomarkers for the diagnosis and followup of patients

Role for high and ultra-high field imaging in the near future ?

Advantages of ultra-high field MRI

Better spectral resolution

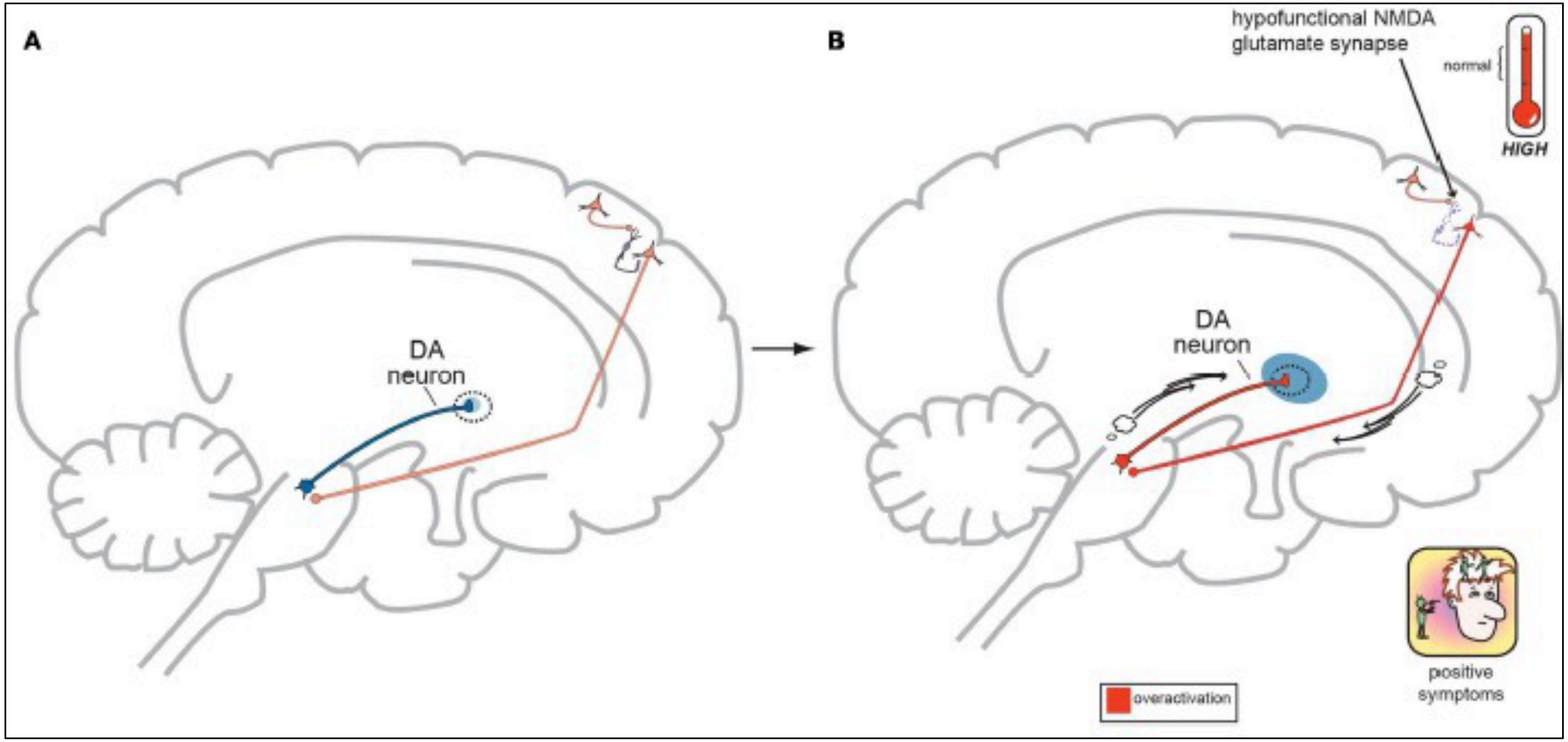
Metabolic evaluation, separation between Glutamate et Glutamine (impossible at lower field strengths)



Tkac et al 2001

Better spectral resolution

→ Validation of metabolic pathophysiological hypotheses, particularly in schizophrenia



Stahl, 4ème édition, 2015

Better spectral resolution

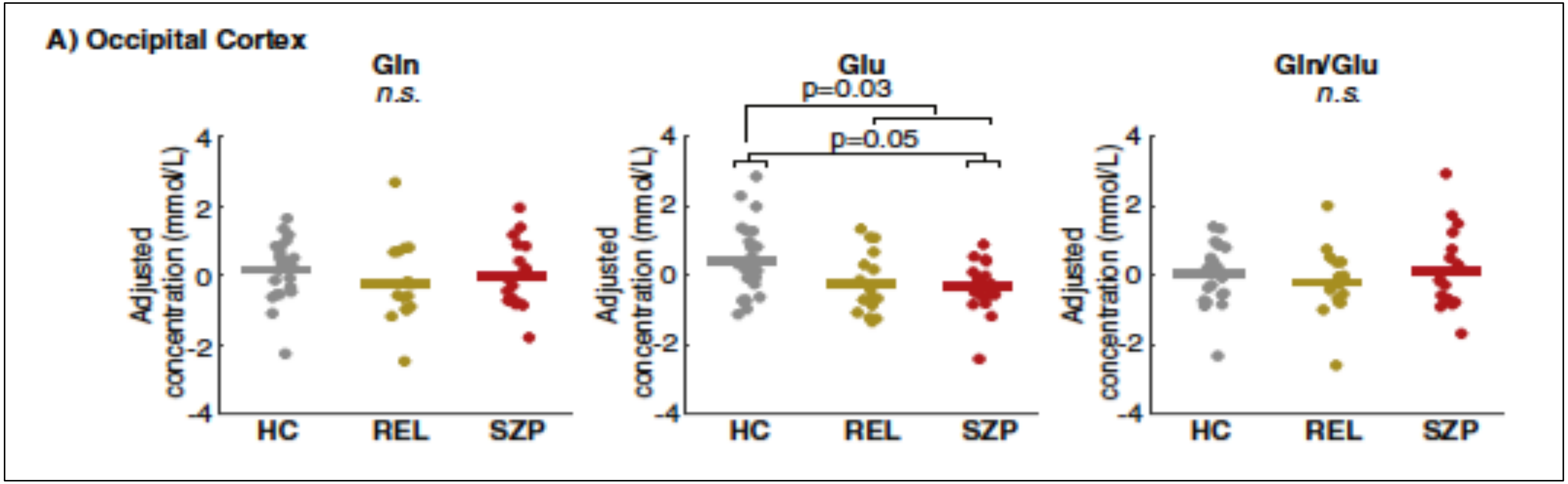
→ Validation of metabolic pathophysiological hypotheses, particularly in schizophrenia

→ Changes in neurotransmitter concentrations in patients with first psychotic event (Wang et al 2019)

Better spectral resolution

→ Validation of metabolic pathophysiological hypotheses, particularly in schizophrenia

→ Perturbation of glutamatergic pathway in related patients (REL ; Thakkar et al 2017)



Better spectral resolution

In vivo modelisation, neurotransmitter anomalies in other mental health diseases

→ Anorexia nervosa (Godlewska et al 2017)

→ Depressive disorders (Taylor et al 2017)

Identification of therapeutic targets and evaluation of effectiveness of potential treatments (Li et al 2016, Cai et al 2012, Masaki et al 2016)

Advantages of ultra high field imaging

Better spectral resolution

Metabolic evaluation, separation between Glutamate and Glutamine not possible at low field

Increased magnetic susceptibility

BOLD effect more pronounced -> improved functional IRM and neuronal network evaluation

Increased magnetic susceptibility

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→ Improved differentiation between oxyhemoglobin-rich arterial blood (following task) and veinous blood (deoxyhemoglobin).

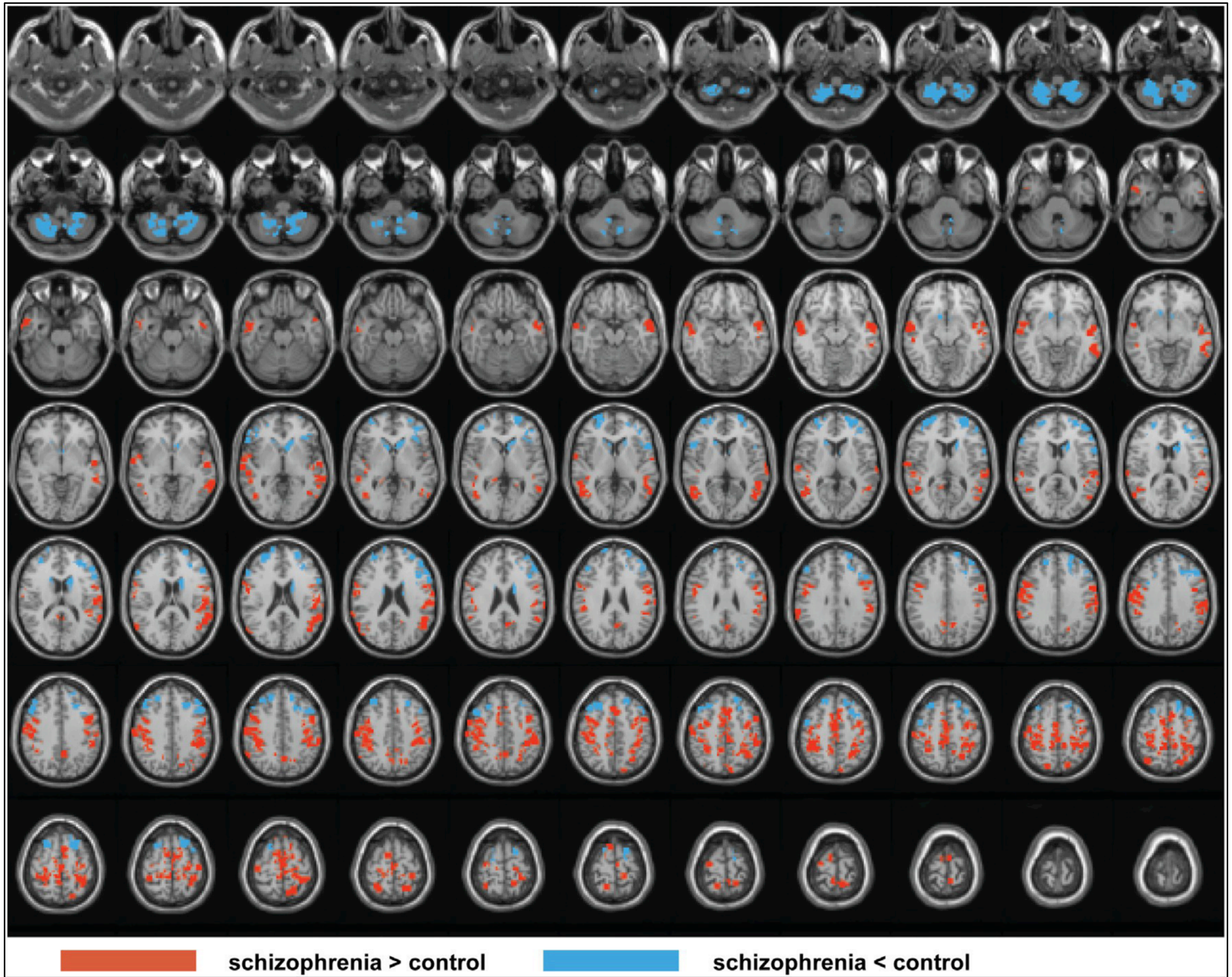
Increased magnetic susceptibility

BOLD effect more pronounced -> improved functional IRM and neuronal network evaluation

→ In patients with schizophrenia, a**lteration of neuronal network**

At rest (réseaux sous corticaux et auditifs, Lottman et al 2019 ; réseaux thalamo corticaux, Hua et al 2019)

During a cognitive task (Overbeek et al 2019)



Hua et al
2019

Increased magnetic susceptibility

BOLD effect more pronounced -> improved functional IRM and neuronal network evaluation

→ fIRM: MRI biomarker for early treatment response?

De-activation of «default-mode network» during task of facial emotion discrimination

= early response to treatment (EDC – Escitalopram ; Spies et al 2017)

Advantages of ultra-high field imaging

Better spectral resolution

Metabolic evaluation, separation between Glutamate and Glutamine not possible at low field

Increased magnetic susceptibility

BOLD effect more pronounced -> improved functional IRM and neuronal network evaluation

Better spatial resolution

Increased precision in morphometric and et volumetric studies

Better spatial resolution

Increased precision in morphometric and et volumetric studies

→ Increased volume of hypothalamus in patients treated vs not treated for mood disorder compared to normals (Schindler et al 2019)

→ Significant correlation betweem volume of habenular complex and severity of depressive disorder in untreated patients (Schmidt et al 2017)

→ Could improve precision of neuroanatomic signature (recognized on lower field imaging, De Pierrefeu et al 2018), allowing to predict transition to psychosis in patients with first psychotic event

Better exploration of physiopathological modeling, validation and large scale study with 3T MRI

Future objectives :
→ Identify new therapeutic targets

→ MRI biomarkers to predict response to treatment to assist diagnosis (in case of atypical clinical presentation or early diagnosis at syndromic stage)

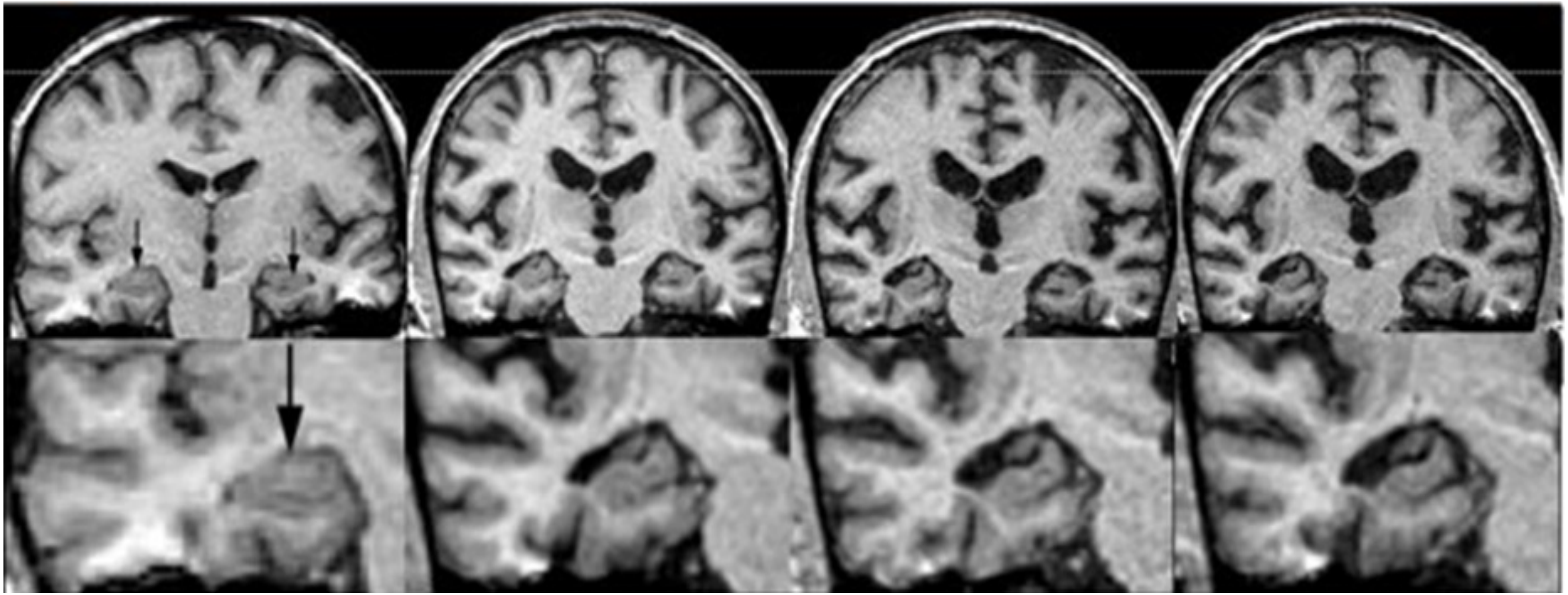
V. CLINICAL APPLICATIONS OF 7T MRI IN NEURODEGENERATIVE DISEASES

A Public Health Problem

- 40% Institutionalized
- 1.3 cases of Alzheimer's disease (AD) in 2020 in France
- Total health care cost (all care, medical and other): 5 Billion Euros/year
    - 53% hospital care / 47% outpatient care
    - 13% in specialized drug cost / 7% imaging cost

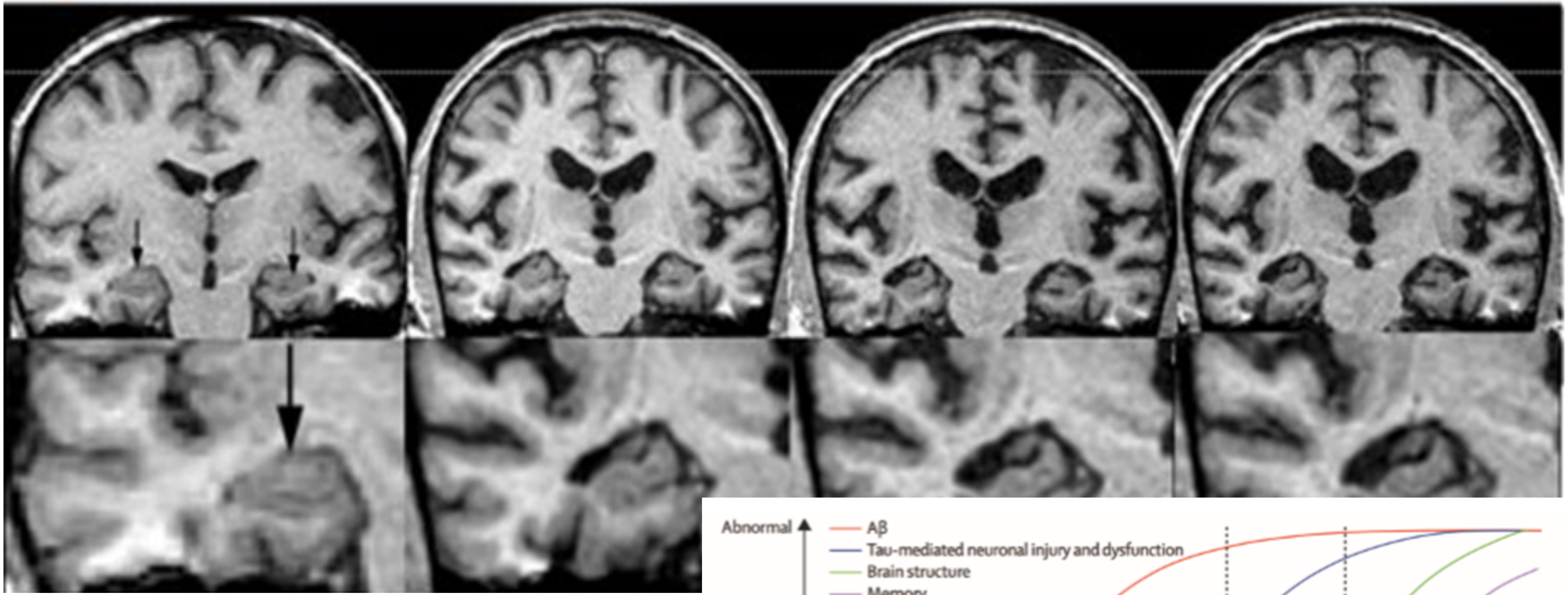
A FEW NUMBERS

AD patients in France | **New cases/year** | **2/3 are women** | **Over 1000 Euros in health care costs for patients/families**



Normal aging | Mild MCI | AD Mild | AD Moderate

Decrease in hippocampal volume in AD | **10%** | **25%** | **40%**

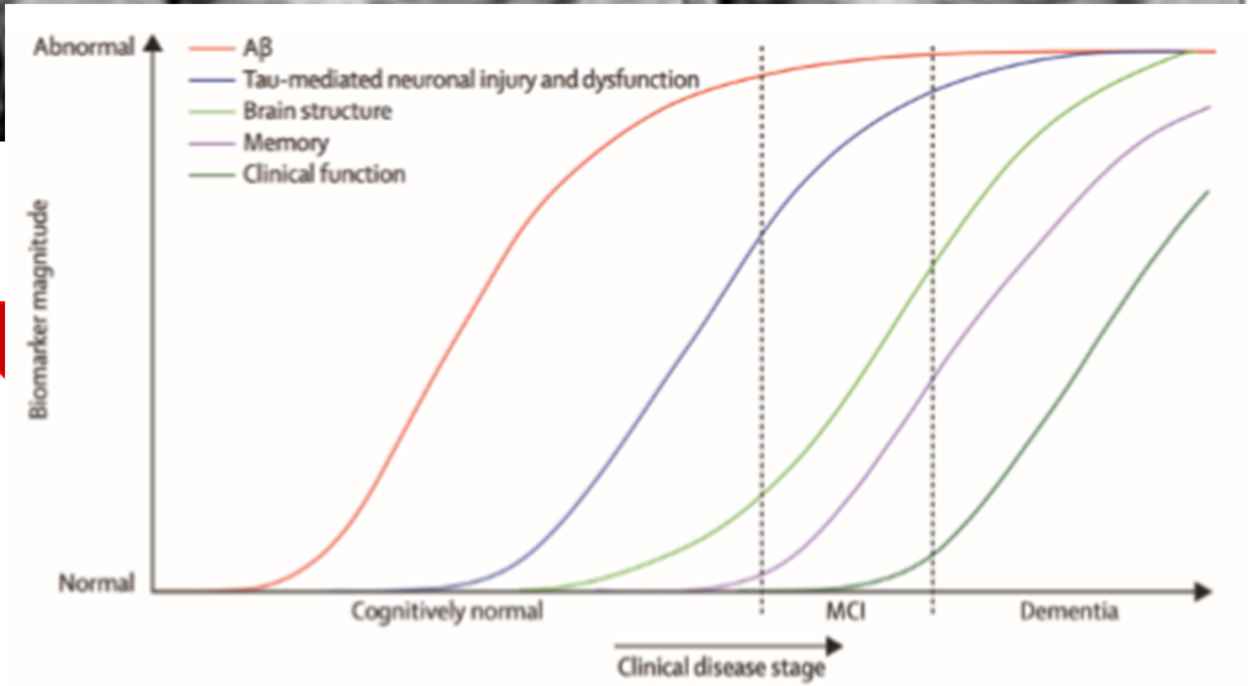


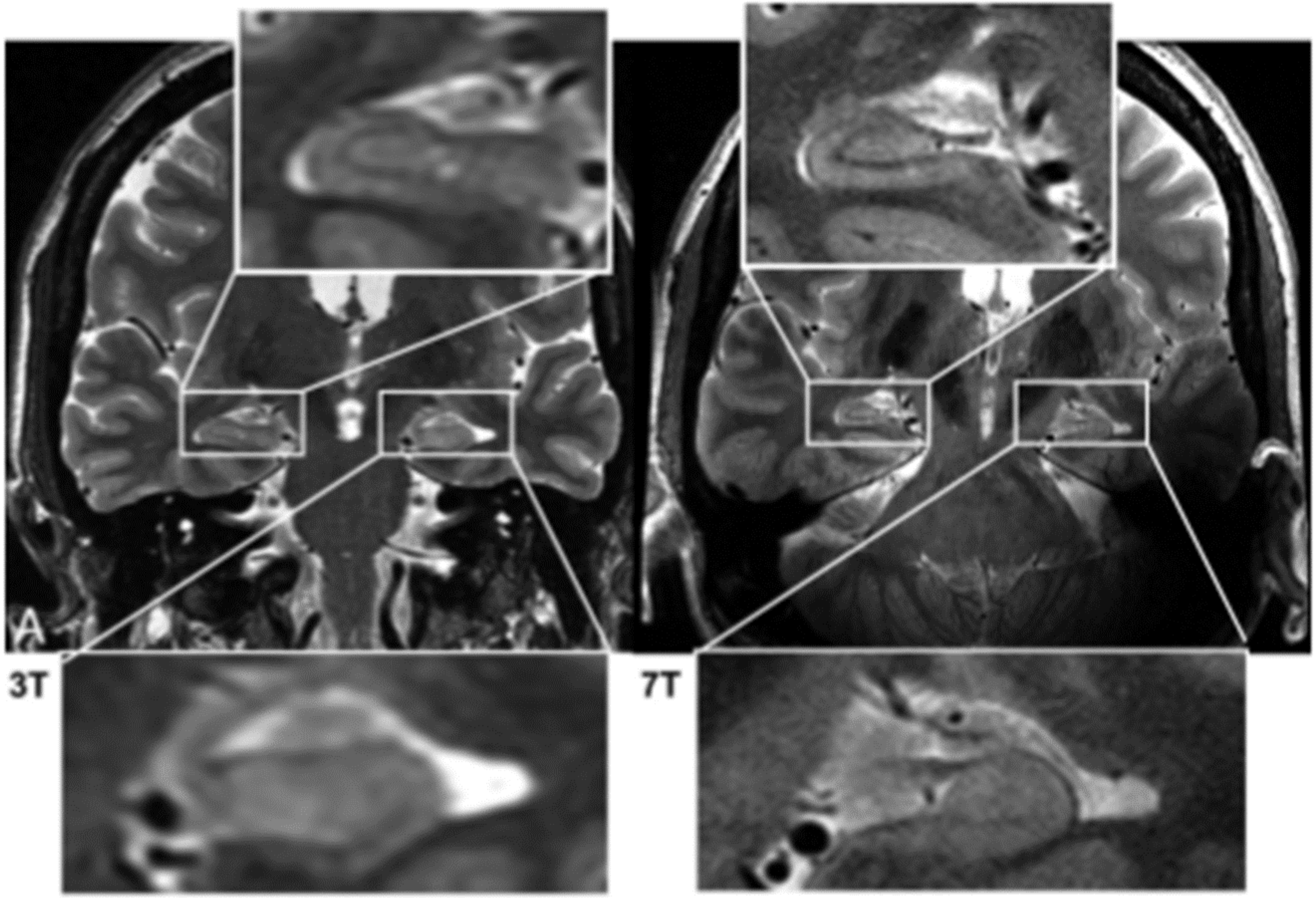
Normal aging

Mild MCI

Decrease in hippocampal volume in AD

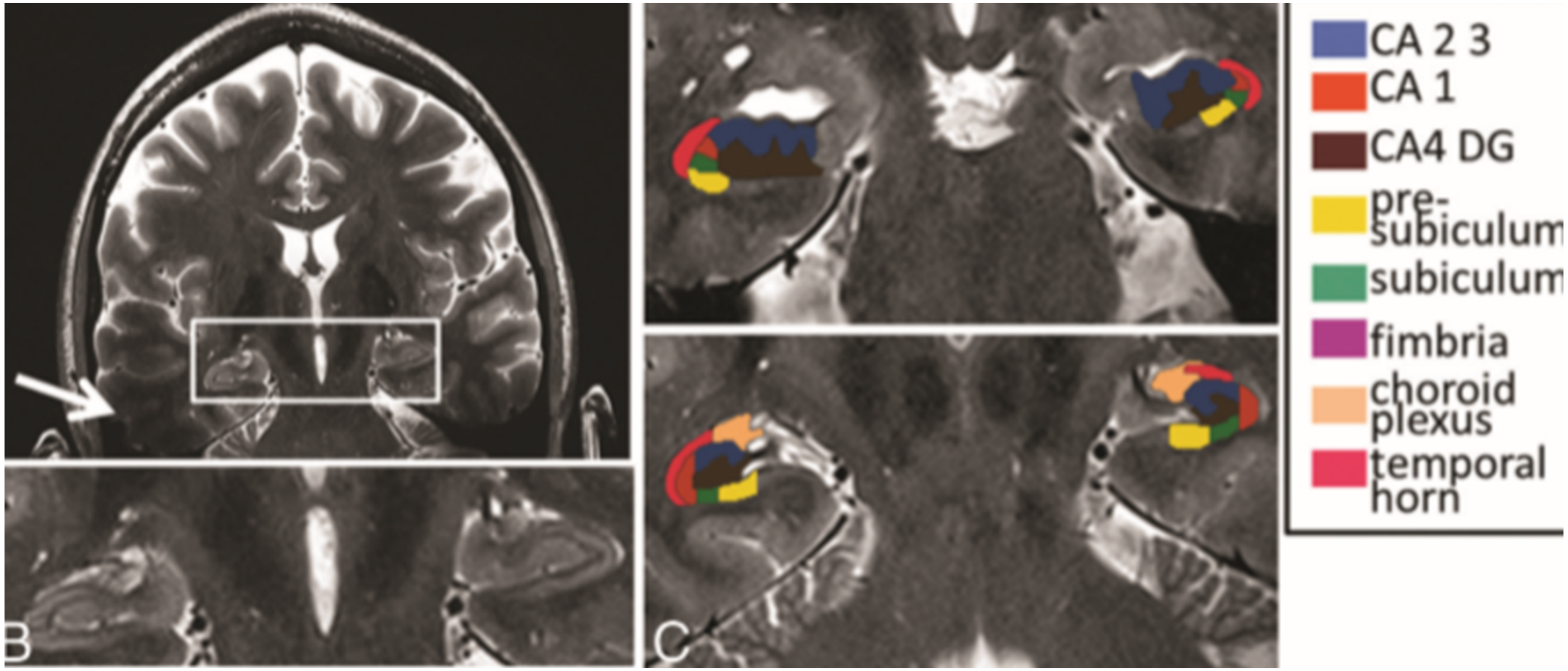
10%

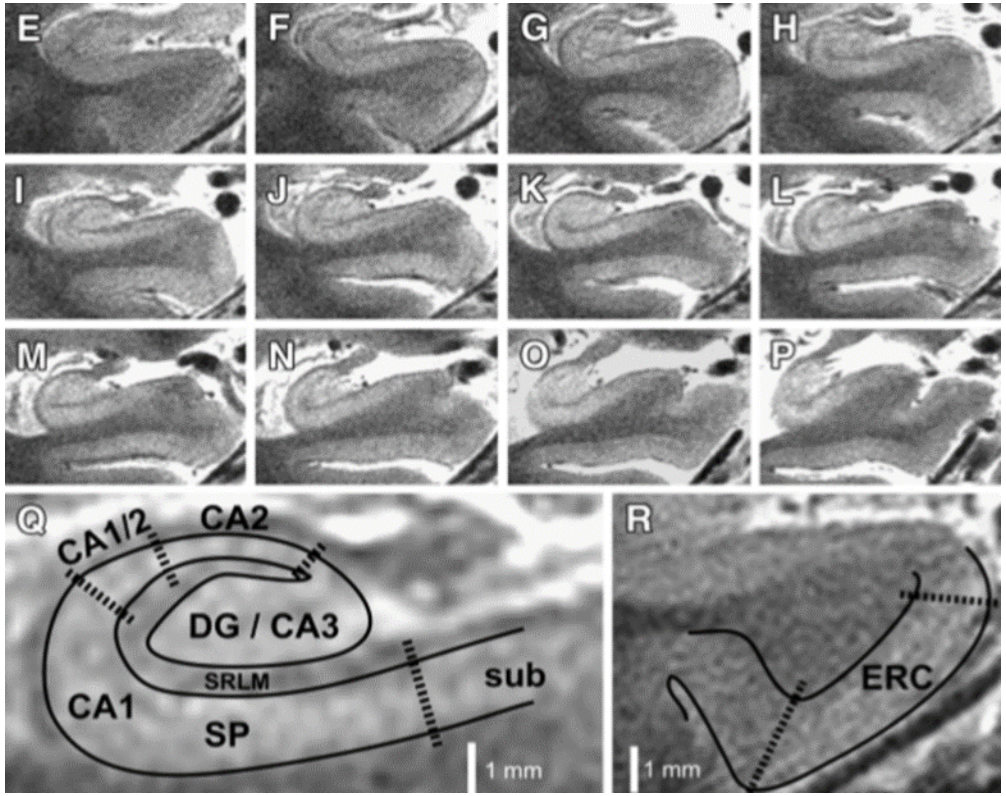


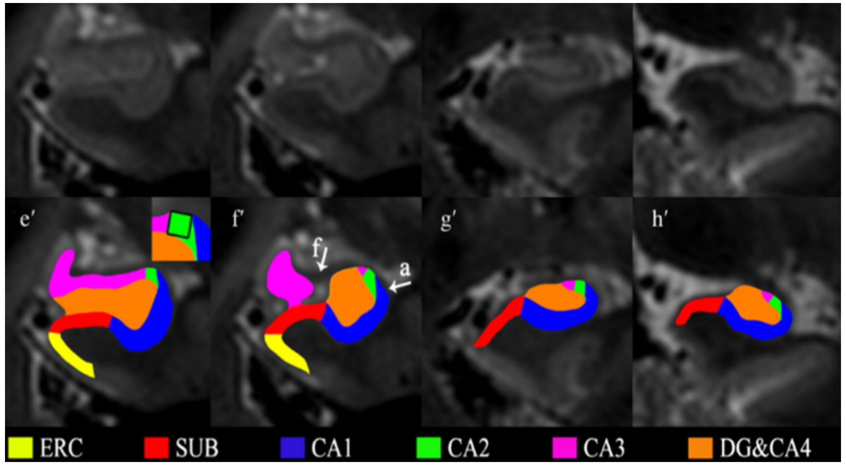


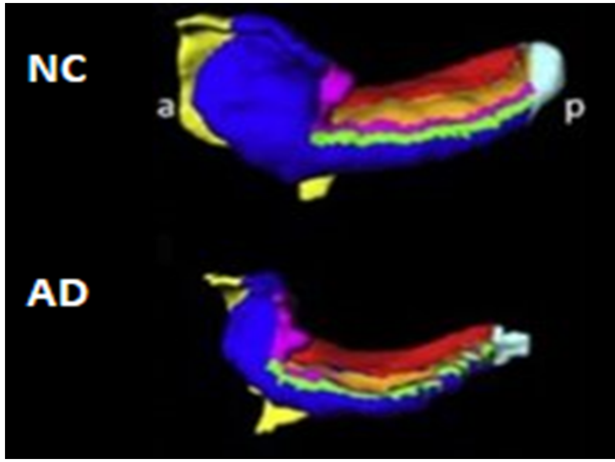
Hippocampal atrophy

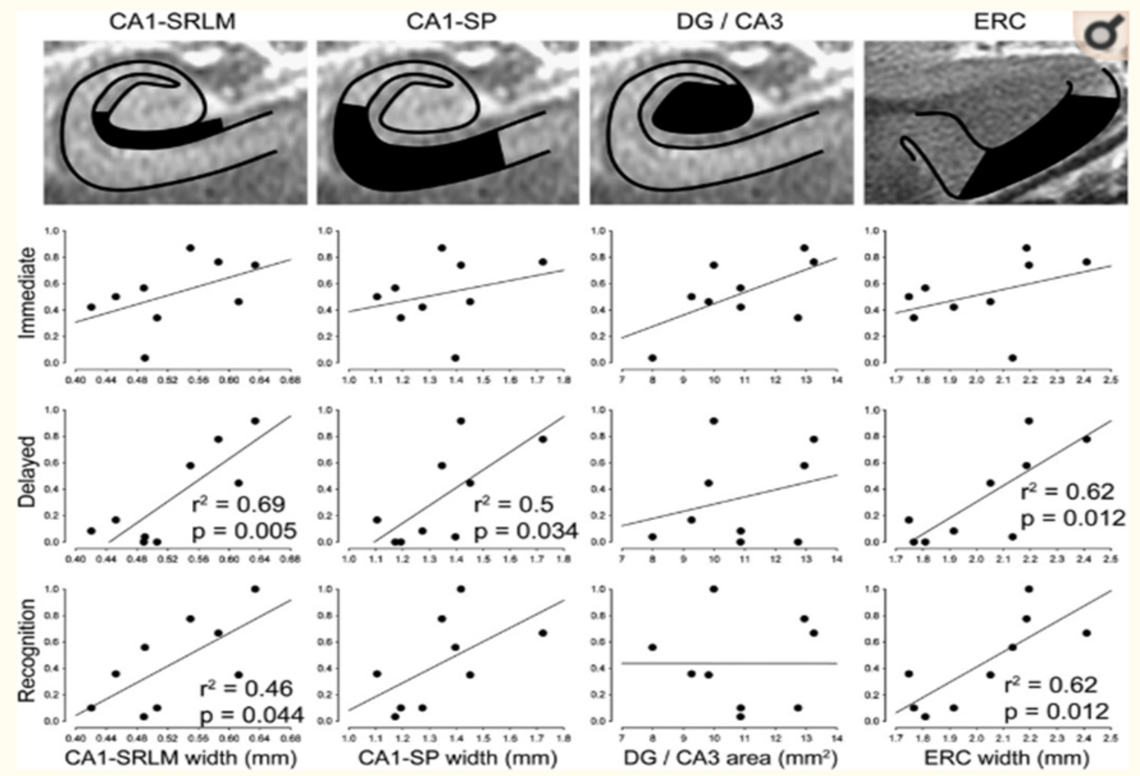
Hippocampal atrophy





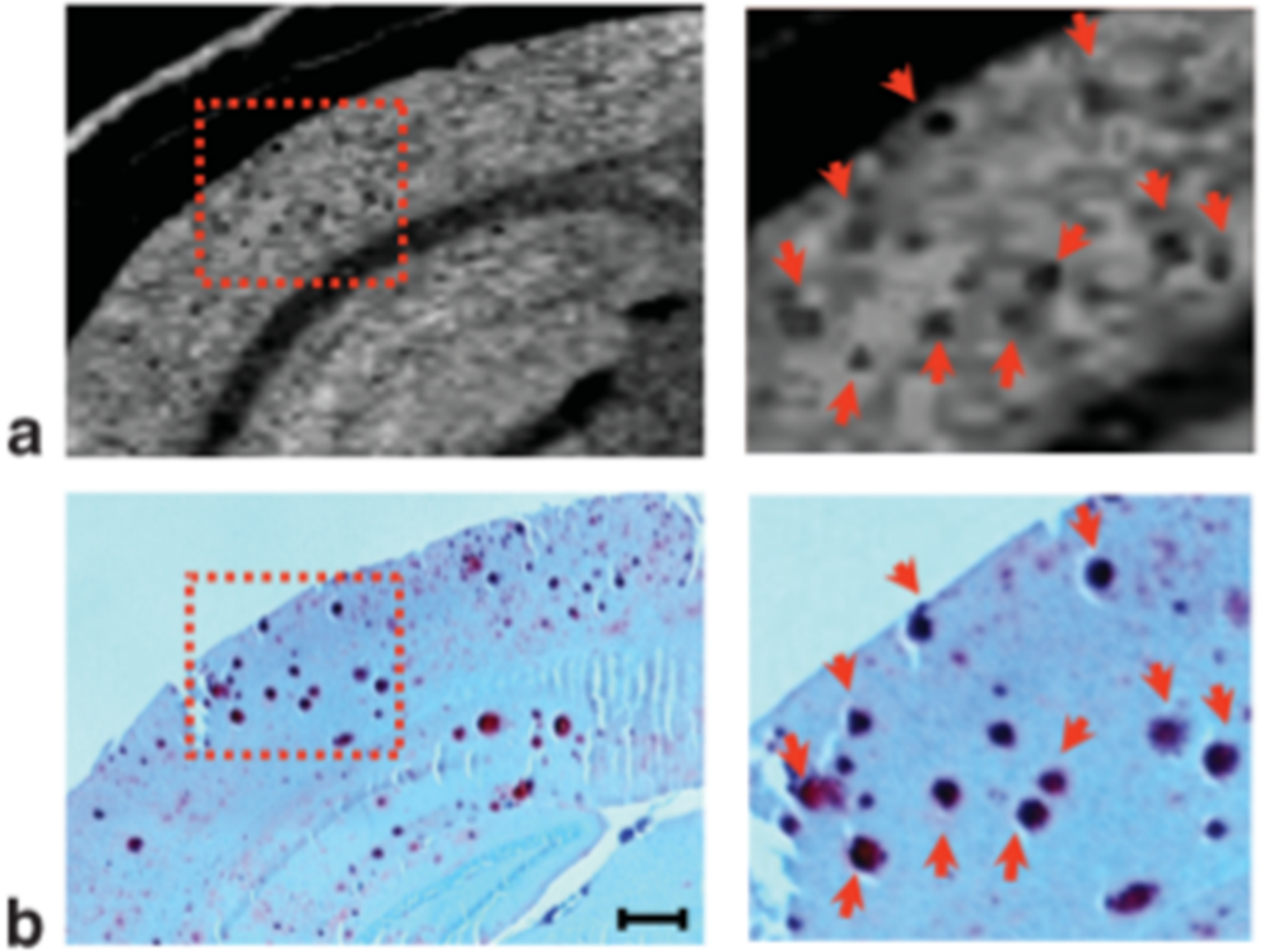




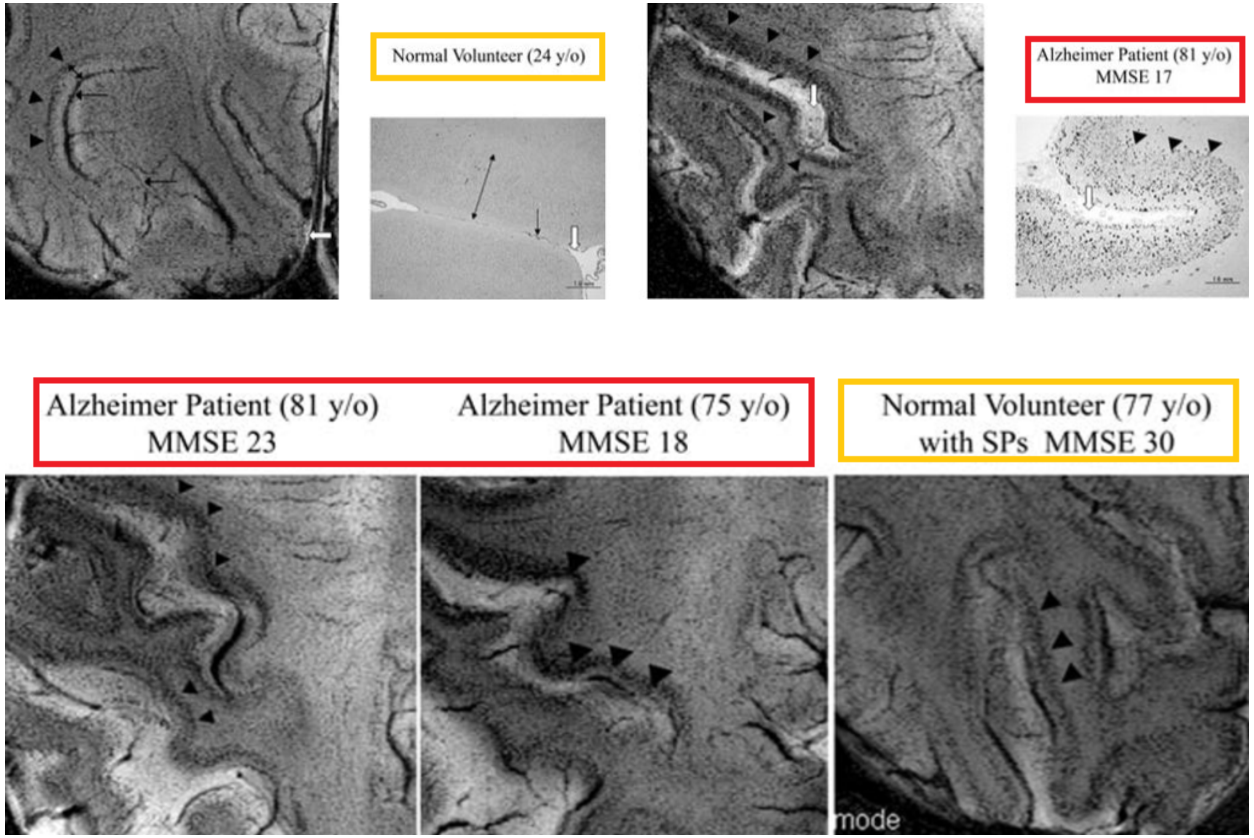


Improved definition of hippocampal sub-zones
Definition of patterns of hippocampal atrophy

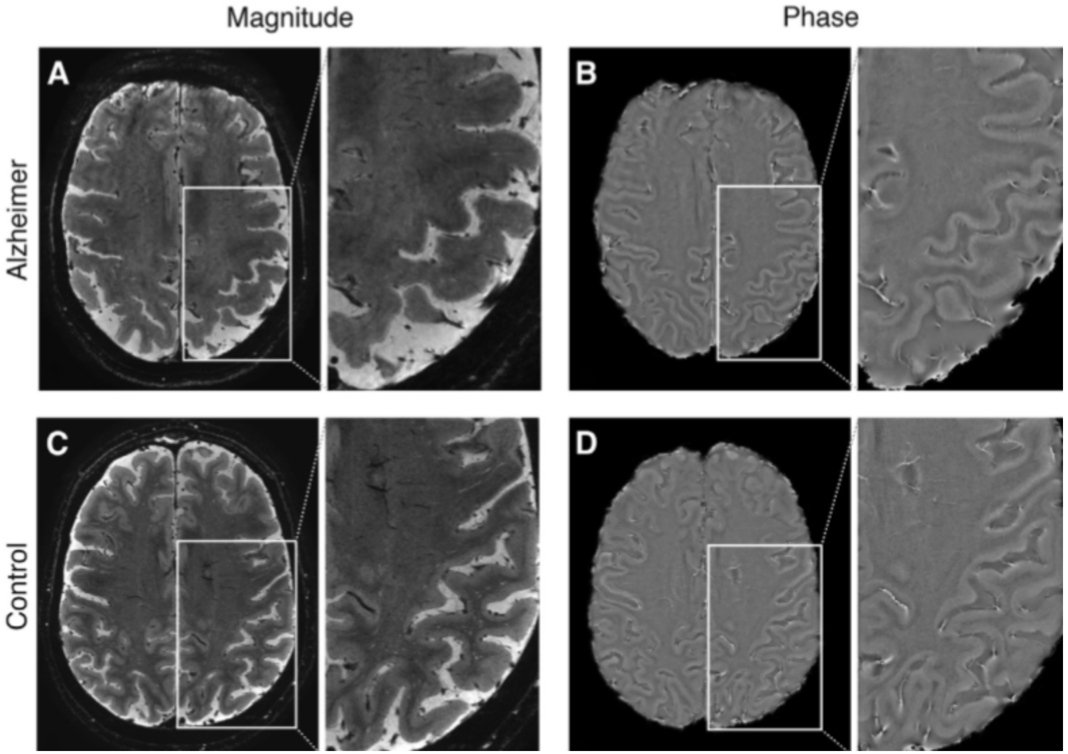
IMAGING AMYLOID PLAQUES



IMAGING AMYLOID PLAQUES



Magnetic resonance microscopy



Phase contrast MR imaging

Perspectives

Other fields of neuroradiology :

→ Drug-resistant partial complex seizures: identification of cortical dysplasia not detectable at lower field (Guye et al 2019).

→ Parkinson's disease (neuromelanin at T2*)

→ Better characterization of smaller anatomical structures: cochlea, olfactory system, etc..

→ Haut de France regional project ARIANES ;

→ Increase in 7T imaging for large scale population studies

VI. REGIONAL PROJECT « ARIANES »

STATE OF PLAY

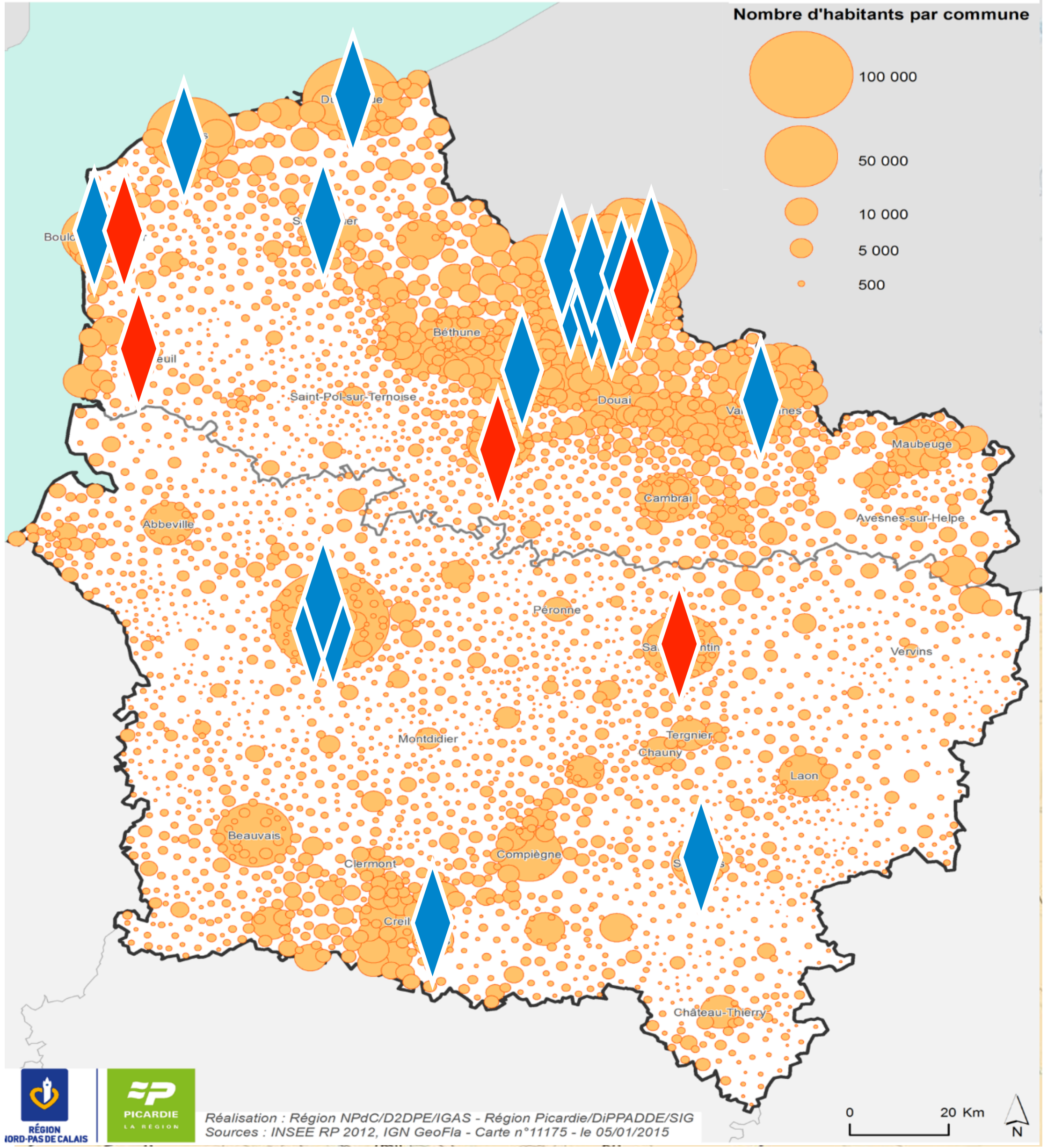
Existing in imaging

A potential grid of 100 +MRI and 150 CT Scan

18 MRI 3 Tesla ◆ and 5 in installation ♦

Healthcare institutions

2 CHU of Lille and Amien
50 hospitals(CH)
80 private clinics



Maillage IRM 3T / 7T - IA

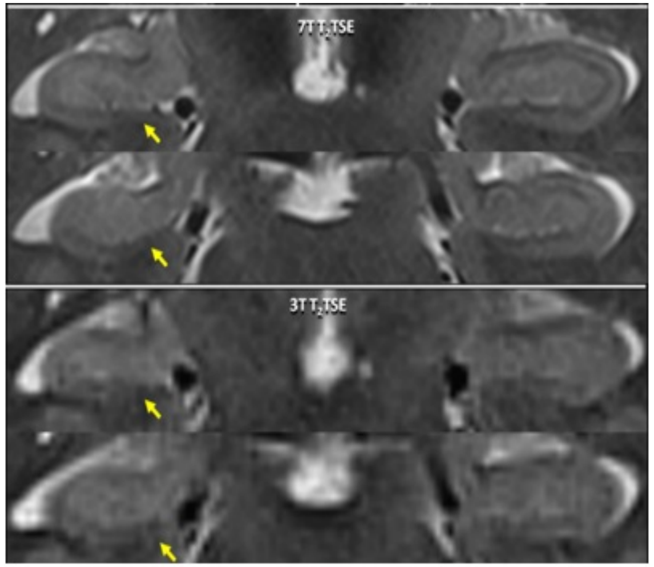
MRI 7T

Identify new 7T MRI biomarkers for a better understanding of the pathophysiology of neurological and psychiatric diseases

Use of 7T biomarkers on cohorts of patients in clinical routine using 3T MRIs from the region

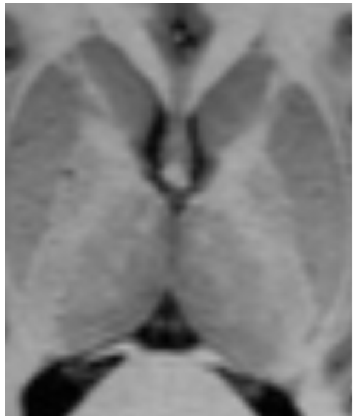
IA

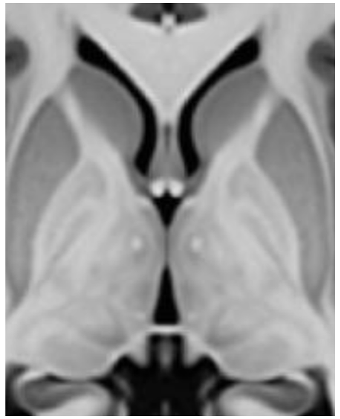
→



Epilepsy : hippocampal asymmetry

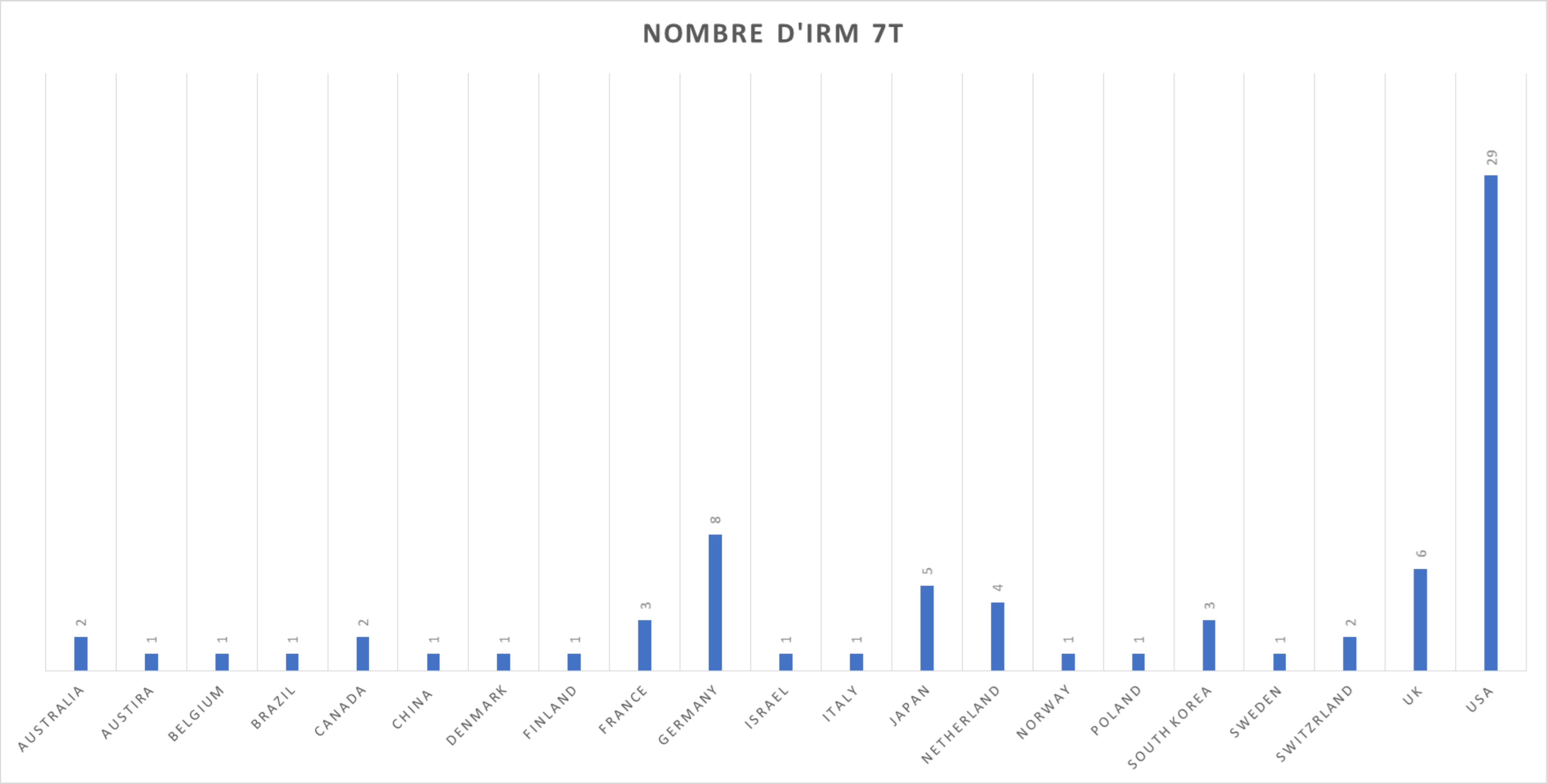
3T





7T

Courtesy of Pr. M. Gueye, CRMBM-CEMEREM, Marseille


NOMBRE D'IRM 7T
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DENMARK
FINLAND
FRANCE
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ISRAEL
ITALY
JAPAN
NETHERLAND
NORWAY
POLAND
SOUTH KOREA
SWEDEN
SWITZRLAND
UK
USA

Country	City	MRI type	University/Organization Name
Australia	Brisbane	7T	Universito of Queensland (Centre for Advanced Imaging)
Australia	Melbourne	7T	University of Melbourne (Royal Melbourne Hospital)
Austria	Vienna	7T	High Field Magnetic Resonance Center
Belgium	Liège	7T	Centre Hospitalier Universitaire (CHU) de Liège
Brazil	São Paulo	7T	University of Sao Paulo (USP - Autopsy Room Imaging Platform)
Canada	London, Onta	7T	Western University of London (Centre for Functional and Metabolic Mappingà
Canada	Montréal	7T	Université McGill
China	Beijing	7T	Chinese Academy of Sciences (State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics)
Denmark	Copenhagen	7T	Danish Research Centre for Magnetic Resonance
Finland	Helsinki	7T	Aalto University
France	Marseille	7T	Centre de Résonance Magnétique Biologique et Médicale
France	Paris-Saclay	11.7T	Atomic Energy Commission (CEA - Neurospin Saclay)
France	Poitiers	7T	Centre Hospitalier Universitaire (CHU) de Poitiers
Germany	Berlin	7T	Helmholtz Association (Max Delbrück Center for Molecular Medicine)
Germany	Bonn	7T	German Center for Neurodegenerative Diseases (DZNE)
Germany	Erlangen	7T	Radiology of the University Hospital Erlangen
Germany	Essen	7T	Erwin L. Hahn Institute for Magnetic Resonance Imaging
Germany	Heidelberg	7T	German Anticancer Research Center (DKFZ - Division of Medical Physics in Radiology)
Germany	Jülich	9.4T	Forschungszentrum Jülich
Germany	Jülich	7T	Forschungszentrum Jülich
Germany	Leipzig	7T	Max Planck Institute for Human Cognitive and Brain Sciences
Germany	Magdenburg	7T	University Otto von Guericke
Germany	Tubingën	9.4T	Max Planck Institute for Biological Cybernetics
Israel	Rehovot	7T	Weizmann Institute of Science
Italy	Pisa	7T	University of Pisa, Fondazione Imago 7
Japan	Iwate	7T	Iwate Medical University (Institue of Biomedical Sciences)
Japan	Kyoto	7T	Kyoto University
Japan	Niigata	7T	University of Niigata (Center for Integrated Human Brain Science)
Japan	Okazaki	7T	National Institute for Physiological Sciences (NIPS)
Japan	Osaka	7T	National Institute of Information and Communications Technology (Center for Information and Neural Networks)

Netherlands	Amsterdam	7T	Spinoza Centre for Neuroimaging
Netherlands	Leiden	7T	Leiden University Medical Center (LUM : Department of Radiology, C.J. Gorter Center for High Field Magnetic Resonanc)
Netherlands	Maastrich	7T	Maastrist University (Scannexus)
Netherlands	Maastrich	9.4T	Maastrist University (Scannexus)
Netherlands	Utrecht	7T	University of Utrecht (Image Sciences Institute, University Medical Center)
USA	New York	7T	Mount Sinai School of Medicine (Translational and Molecular Imaging Institute)
Norway	Trondheim	7T	Norwegien University of Science and Technology (NTNU)
Poland	Lublin	7T	Medical University of Lublin
South Kore	Daejeon	7T	Korea Basic Science Institute
South Kore	Incheon	7T	Gachon University of Medicine and Science (Neuroscience Research Institute)
South Kore	Suwon	7T	Sungkyunkwan University (IBS Center for Neuroscience Imaging Research)
Sweden	Lund	7T	Lund University (Bioimaging Center)
Switzerland	Lausanne	7T	Ecole Polytechnique Fédérale de Lausanne (CIBM : Center for Biomedical Imaging)
Switzerland	Zürich	7T	ETH Zurich (Institute of Chemical and Bioengineering)
UK	Cambridge	7T	Cambridge (Wolfson Brain Imaging Centre)
UK	Cardiff	7T	Cardiff University (CUBRIC : Cadriff University Brain Research Imaging Centre)
UK	Glasgow	7T	University of Glasgow (ICE)
UK	London	7T	King's College of London
UK	Nottingham	7t	Sir Peter Mansfield Magnetic Resonance Centre
UK	Oxford	7T	Oxford Centre for Functional MRI of the Brain
USA	Auburn	7T	Auburn University
USA	Austin	7T	Cancer Prevention & Research Institute of Texas
USA	Baltimore	7T	Kennedy Krieger Institute
USA	Bethesda	7T	NIH
USA	Bethesda	7T	NIH
USA	Bethesda	11.7T	NIH
USA	Boston	7T	Harvard (Brigham and Women's Hospital)
USA	Boston	7T	Massachusetts General Hospital
USA	Chapel Hill	7T	University of North Carolina (UNC – Biomedical Research Imaging Center)
USA	Chicago	9.4T	UIC Center for Magnetic Resonance Research
USA	Cleveland	7T	Cleveland Clinic Foundation
USA	Columbus	8T	The Ohio State University
USA	Coralville	7T	University of Iowa Health Care
USA	Dallas	7T	UT Southwestern Imaging Center
USA	Los Angele	7T	University of Southern California Health Sciences Campus
USA	Milwaukee	7T	Medical College of Wisconsin Center for Imaging Research
USA	Minneapolis	7T	Center for Magnetic Resonance Research
USA	Minneapolis	7T	Center for Magnetic Resonance Research
USA	Minneapolis	9.4T	Center for Magnetic Resonance Research
USA	Minneapolis	10.5T	Center for Magnetic Resonance Research
USA	Minneapolis	7T	Mayo Clinic
USA	Nashville	7T	Vanderbilt University Institute of Imaging Science
USA	New Haven	7T	Columbia University
USA	New Haven	7T	Yale University (MRRC – Magnetic Resonance Research Center)
USA	New York	7T	New York University (Department of Radiology, Center for Biomedical Imaging)
USA	Philadelphia	7T	University of Pennsylvania (Center for Magnetic Resonance and Optical Imaging)
USA	Pittsburg	7T	University of Pittsburgh (Magnetic Resonance Research Center)
USA	Portland	7T	Oregon Health Sciences University (Advanced Imaging Research Center)
USA	Rochester	7T	Mayo Clinic
USA	San Francis	7T	San Francisco Valley Medical Center
USA	San Francis	7T	University of California, San Francisco (UCSF – Department of Radiology & Biomedical Imaging)
USA	Stanford	7T	Stanford Medical School

APPLICATION DE L'IRM 7T EN NEURORADIOLOGIE

THANK YOU !