

Imaging avanzato e Ricostruzione multimodale

Anna E Vaudano, MD, PhD
Dipartimento di Scienze Biomediche, Metaboliche e Neuroscienze
Università degli Studi di Modena e Reggio Emilia





Nessun Conflitto di Interesse



L'utilizzo di protocolli di RM adeguati e dedicati, contribuisce a identificare lesioni potenzialmente epilettogene in pazienti con epilessia focale (insieme a una valutazione multidisciplinare)

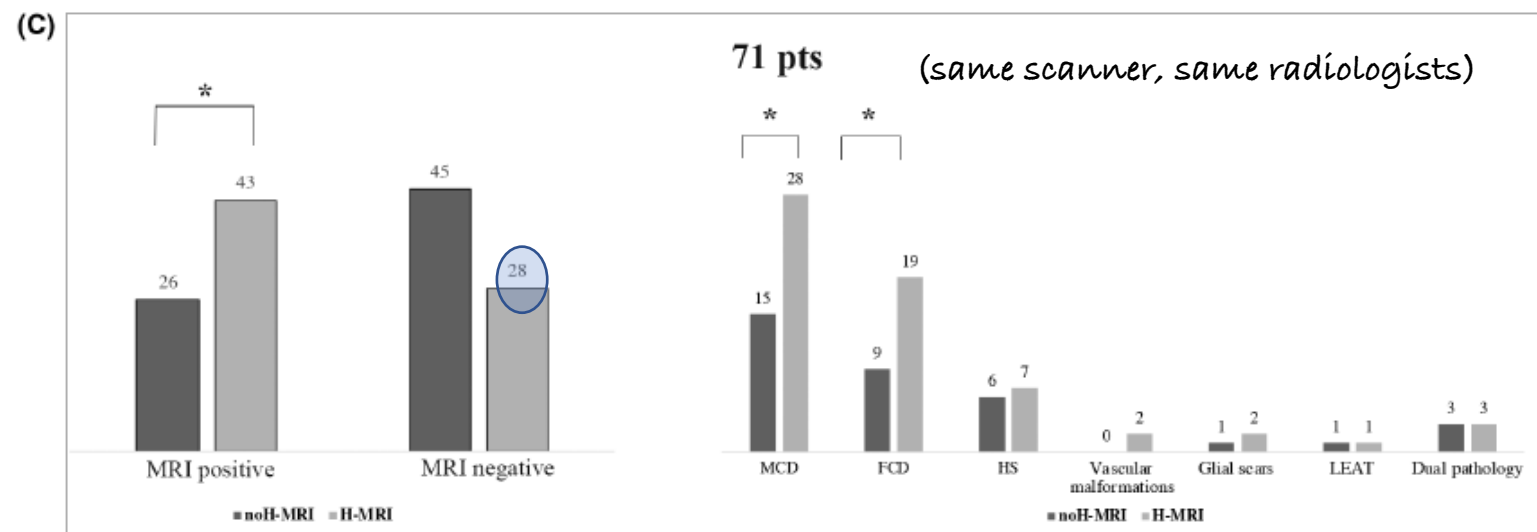
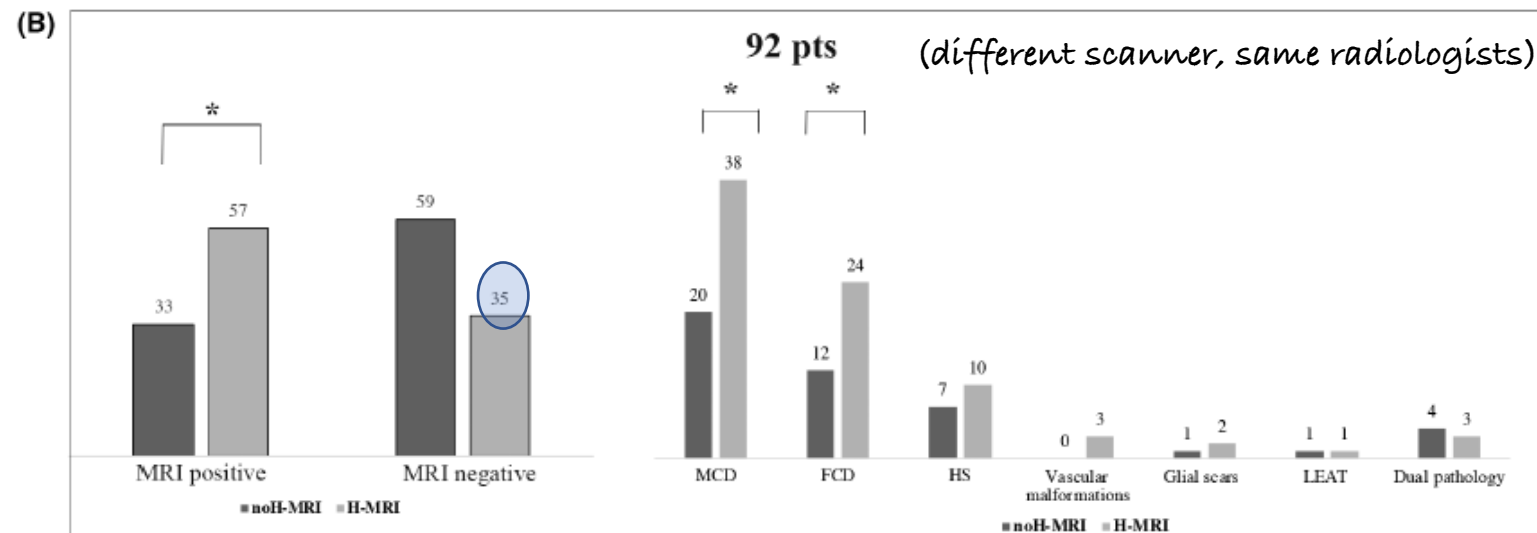
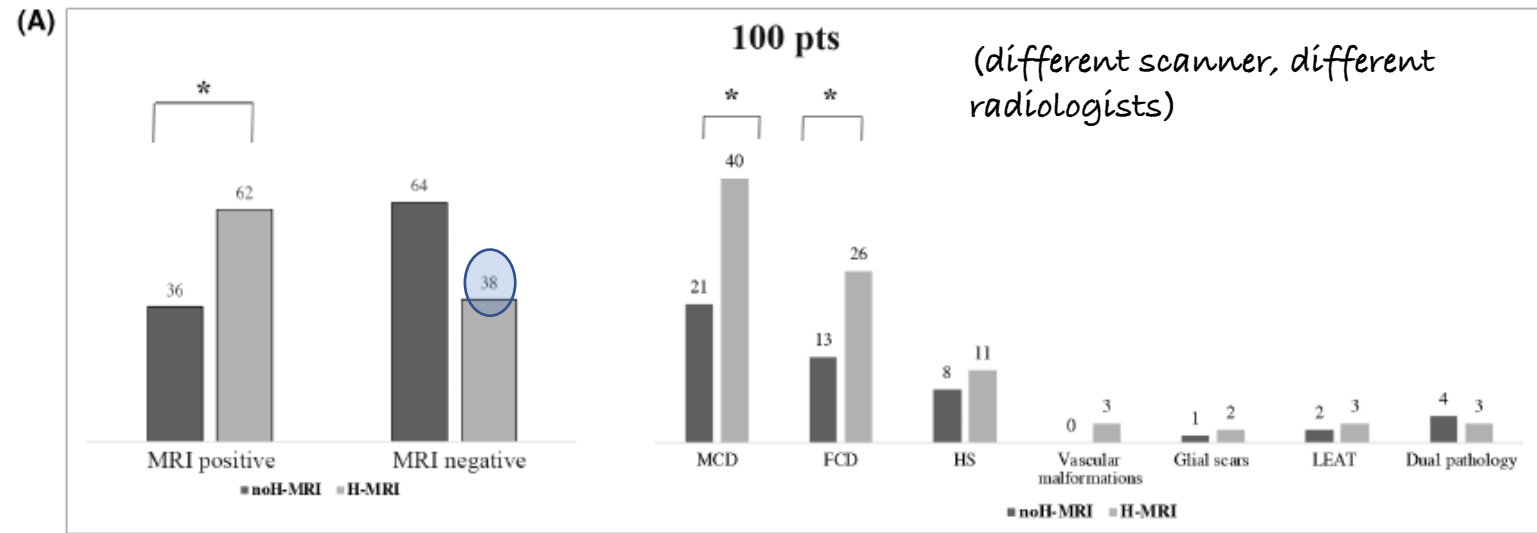
HARmonized NEuroimaging of Epilepsy Structural Sequences (HARNES-MRI) protocol



Table 2. Mandatory and optional sequences of the HARNES-MRI protocol (Bernasconi *et al.*, 2019).

Name (abbreviation/vendor)	Advantages		
Mandatory sequences – HARNES MRI protocol			
Magnetization-prepared rapid gradient-echo (MPRAGE, Siemens), Spoiled gradient-echo (SPGR, GE), Turbo field echo (TFE, Phillips)	T1-weighted	3D	High-resolution images that can be reformatted to be viewed on coronal, axial and sagittal planes Optimal visualization of brain anatomy and morphology
3D fluid attenuation inversion recovery (FLAIR)	T2-weighted	3D	3D high-resolution images that can be reformatted to any plane Cerebrospinal fluid nulling enhances visibility of epileptic pathologies such as focal cortical dysplasia, hippocampal sclerosis, tubers, hamartomas, glial scars, <i>etc.</i>
Coronal spin echo (acquisition plane perpendicular to the long axis of the hippocampus)	T2-weighted	2D	High in-plane resolution Optimal visualization of hippocampal internal structure on coronal cuts
Optional sequences			
Gadolinium-enhanced MRI	T1-weighted	3D	Best for assessing tumor-like lesions, vascular malformations, or infectious processes
Susceptibility weighted imaging	T2*-weighted	3D	Sensitive to iron deposits, blood products and calcifications

Wang *et al.*, 2020





L'utilizzo di protocolli di RM adeguati e dedicati, contribuisce a identificare lesioni potenzialmente epilettogene in pazienti con epilessia focale, *ma persiste un 40% di RM «negative»*



il riscontro di una lesione alla MRI strutturale è un fattore condizionante l'outcome favorevole dopo chirurgia (Bien et al., 2011; Bernasconi et al., 2019)



FCD type 1 sono «perse» alla ispezione visiva nel 30% (Wang et al., 2015), FCD type II nel 20-30% (Tassi et al., 2002; Widdess-Walsh et al., 2005; Krsek et al., 2008)

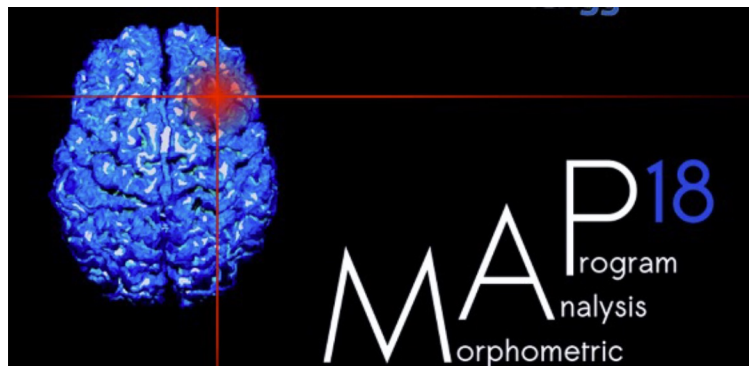


Analisi di post-processing aumentano la «detection rate» dal 30% al 78% (Gill et al., 2021; Wagner et al., 2011)



Structural MRI

Voxel-based (pts versus CRT)



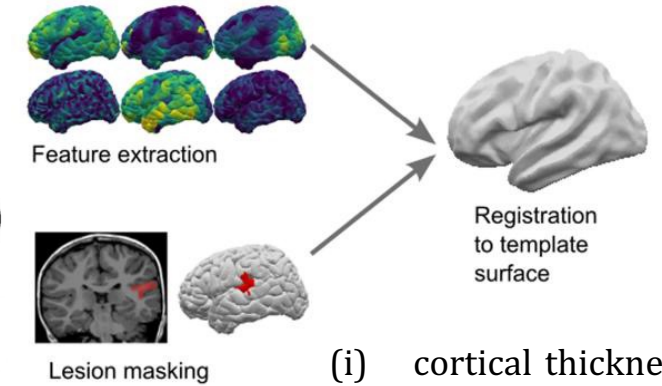
Huppertz et al., 2011

Surface-based Vs CRT



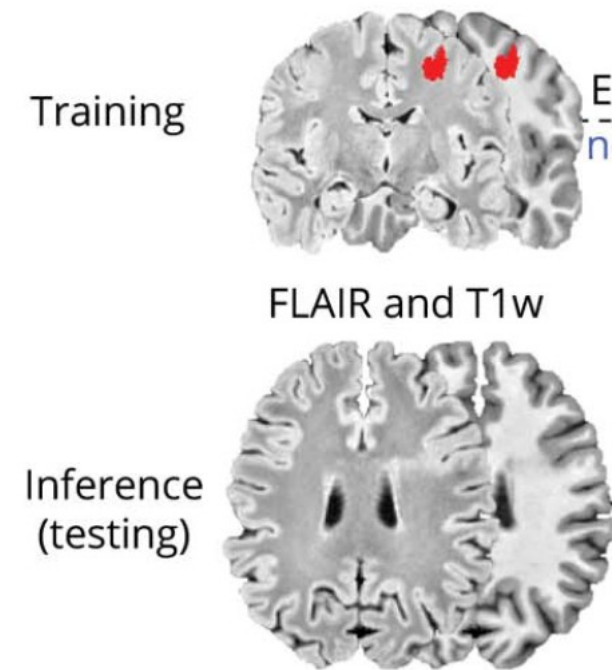
Spitzer et al., 2022

A Site level data processing



- (i) cortical thickness;
- (ii) sulcal depth;
- (iii) intrinsic curvature;
- (iv) Mean curvature
- (v) grey-white contrast;

Deep learning from manually labelled FCD

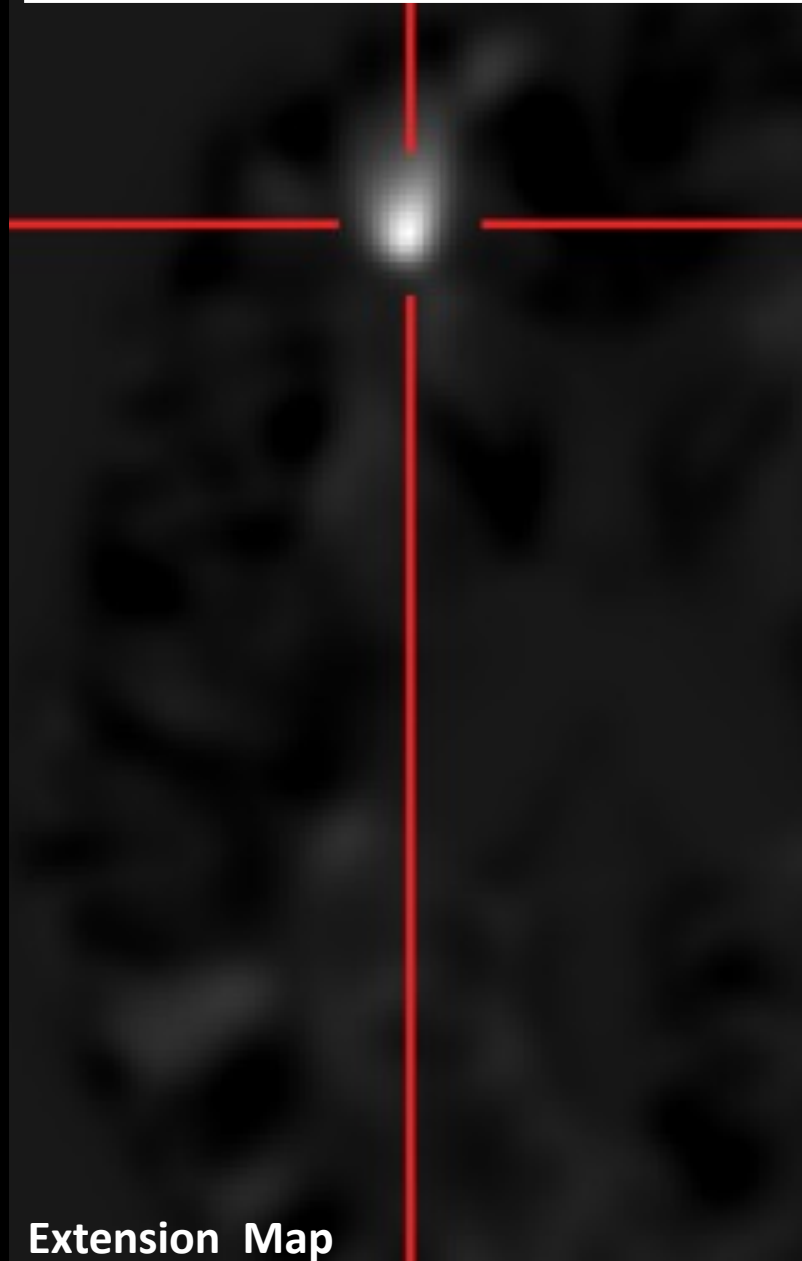


Gill et al., 2021

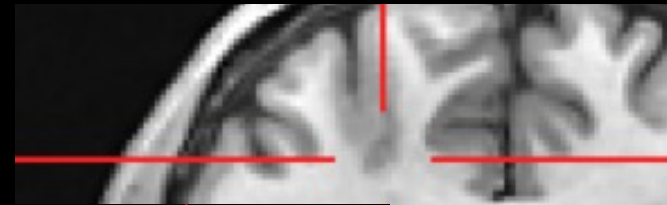
blurring of the gray-white matter junction



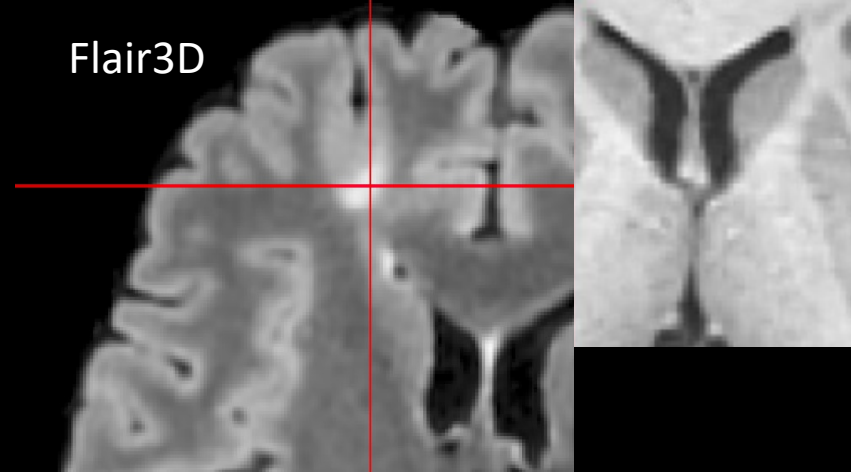
abnormal gyration and extension of gray matter into white matter



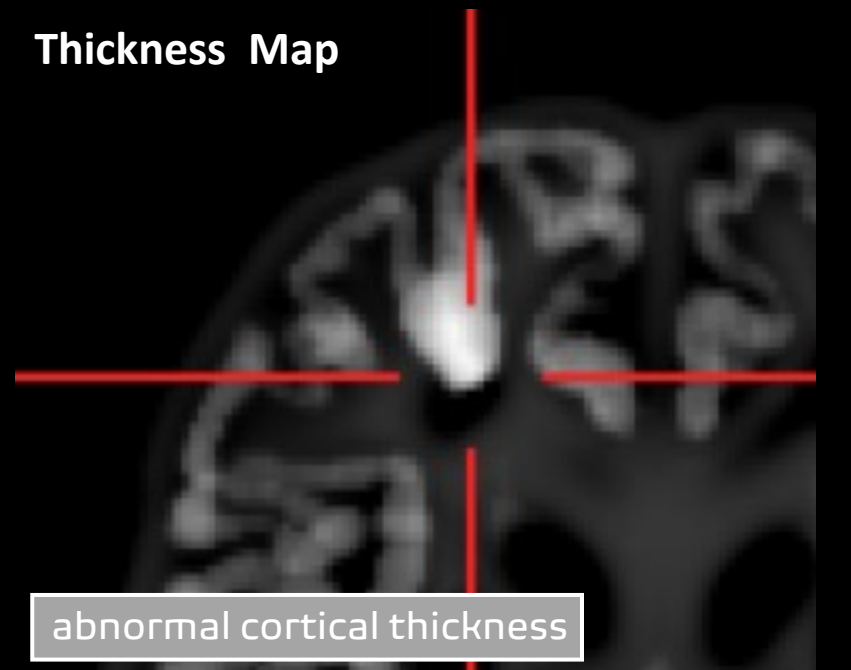
t13D



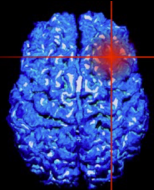
Flair3D

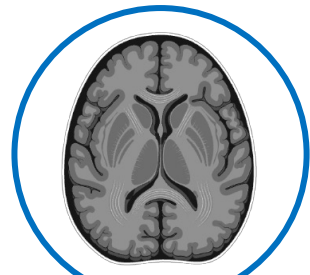


Thickness Map

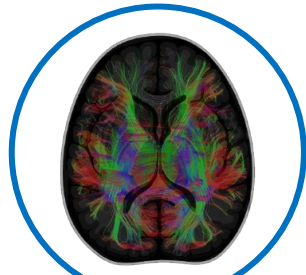


abnormal cortical thickness

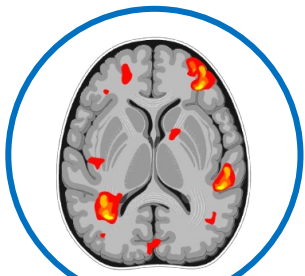




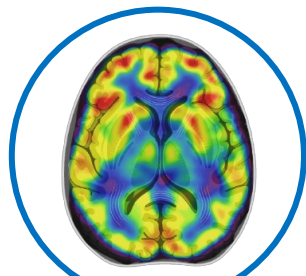
Structural MRI



Diffusion MRI



Functional MRI

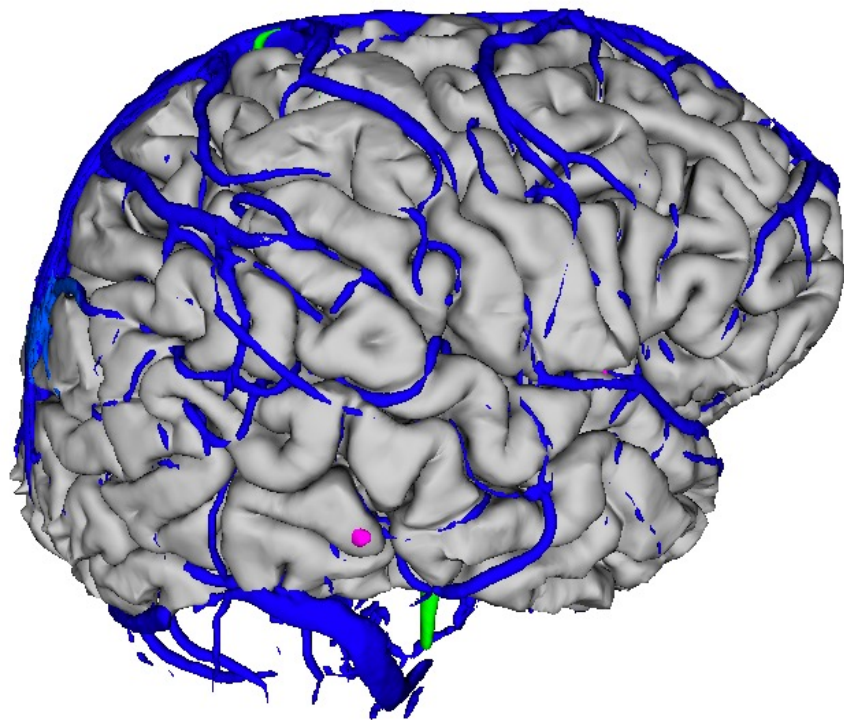
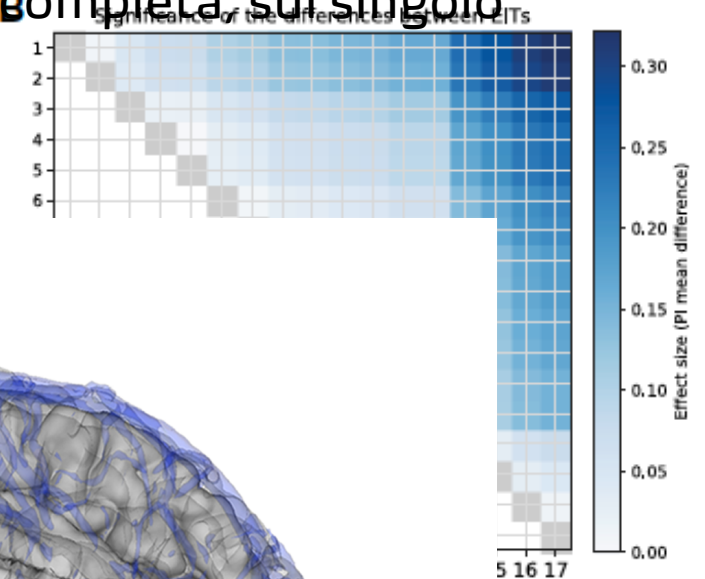
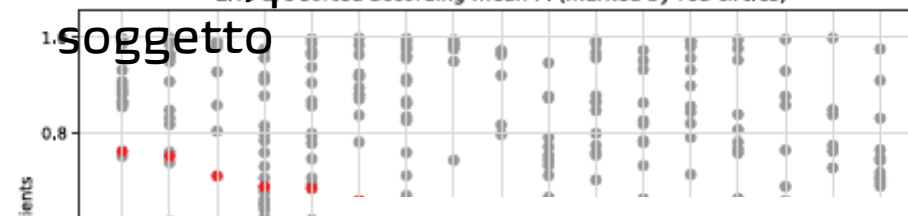


PET

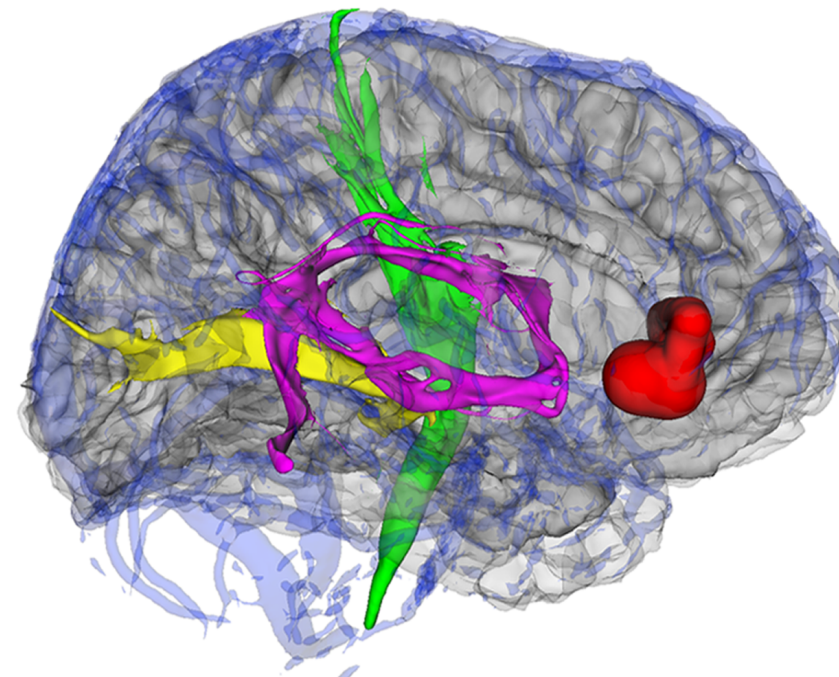
Lo studio delle epilessie focali sta sempre più diventando MULTIMODALE (Jin et al., 2021; Bernasconi & Bernasconi 2021)

Diverse metodiche di imaging contribuiscono come in un puzzle a svelare la EZ in RMN poco informative (Rina et al., 2022)

Le informazioni delle diverse metodiche devono essere «fuse» A insieme per avere una informazione completa, sul singolo



nick
st
is
it
E
)



Is
(1)
EThc,

required MRI sequences: T1W, ASL, DTI, fMRI (+ PET/SPECT)



Article

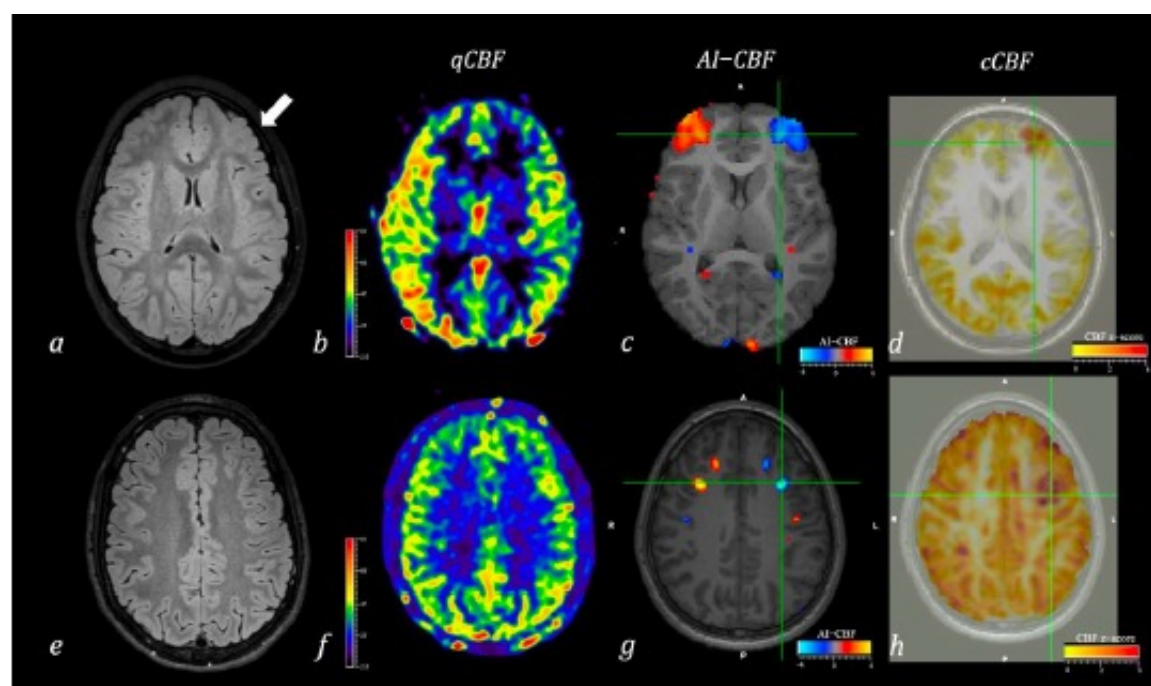
Comparison of Qualitative and Quantitative Analyses of MR-Arterial Spin Labeling Perfusion Data for the Assessment of Pediatric Patients with Focal Epilepsies

2022

Domenico Tortora ^{1,*}, Matteo Cataldi ^{2,3}, Mariasavina Severino ^{1,*}, Alessandro Consales ⁴, Mattia Pacetti ⁴, Costanza Parodi ¹, Fiammetta Sertorio ¹, Antonia Ramaglia ¹, Erica Cognolato ^{2,3}, Giulia Nobile ^{2,3}, Margherita Mancardi ², Giulia Prato ², Laura Siri ², Thea Giacomini ², Pasquale Striano ^{3,5}, Dario Arnaldi ^{3,6}, Gianluca Piatelli ⁴, Andrea Rossi ^{1,7} and Lino Nobili ^{2,3}

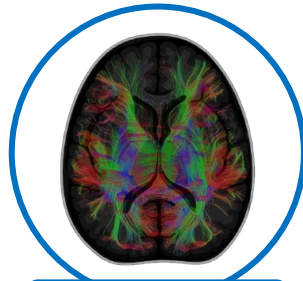
Table 1. Comparisons of three ASL analyses with the electro-clinical definition of the presumed Seizure Onset Zone (SOZ).

	qASL			AI-CBF			cCBF		
	SOZ (%)	SOZ Lateralization Agreement Cohen's Kappa (95% CI)	Brain Lobe Agreement	SOZ (%)	SOZ Lateralization Agreement Cohen's Kappa (95% CI)	Brain Lobe Agreement	SOZ (%)	SOZ Lateralization Agreement Cohen's Kappa (95% CI)	Brain Lobe Agreement
MRI positive 26 patients	7/26 (27%)	0.392 (0.211–0.398)	<ul style="list-style-type: none"> Concordant: 5/26 Partially concordant: 2/26 Discordant ipsilateral: 1/26 Discordant contralateral: 4/26 Uninformative: 14/26 	19/26 (73%)	0.909 (0.891–0.927)	<ul style="list-style-type: none"> Concordant: 14/26 Partially concordant: 5/26 Discordant ipsilateral: 3/26 Discordant contralateral: 1/26 Uninformative: 3/26 	20/26 (77%)	0.943 (0.885–0.968)	<ul style="list-style-type: none"> Concordant: 14/26 Partially concordant: 6/26 Discordant ipsilateral: 4/26 Discordant contralateral: 0/26 Uninformative: 2/26
MRI negative 39 patients	7/39 (18%)	0.385 (0.160–0.336)	<ul style="list-style-type: none"> Concordant: 4/39 Partially concordant: 3/39 Discordant ipsilateral: 1/39 Discordant contralateral: 0/39 Uninformative: 31/39 	18/39 (46%)	0.819 (0.796–0.842)	<ul style="list-style-type: none"> Concordant: 6/39 Partially concordant: 12/39 Discordant ipsilateral: 5/39 Discordant contralateral: 1/39 Uninformative: 15/39 	25/39 (64%)	0.932 (0.896–0.941)	<ul style="list-style-type: none"> Concordant: 11/39 Partially concordant: 14/39 Discordant ipsilateral: 5/39 Discordant contralateral: 2/39 Uninformative: 7/39

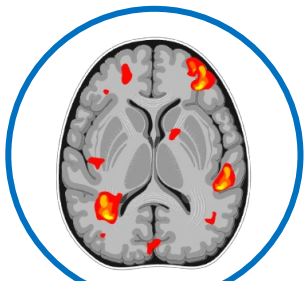




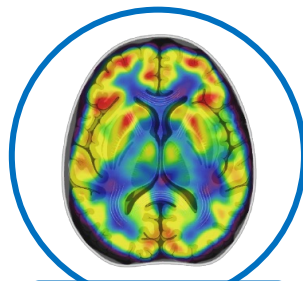
Structural MRI



Diffusion MRI



Functional MRI



PET

Una pipeline di analisi imaging multimodale:

- User-friendly (il suo utilizzo non richieda competenze di coding)
- Che consenta di analizzare simultaneamente più metodiche (strutturali e funzionali)
- A struttura modulare, con moduli tra loro indipendenti e automatica
- Paziente specifica → tutti i risultati sono mostrati nello spazio del paziente e le informazioni delle singole metodiche «fuse» insieme
- Esportabile in diversi centri (dal I al III livello) con diversi scanner e parametri delle sequenze



- i. Riconoscimento di un maggior numero di lesioni epilettogene
- ii. Maggior numero di pazienti candidati alla chirurgia
- iii. Incrementare le competenze di analisi di imaging multimodale in un maggior numero di epilettologi e radiologi

NeuroImage 263 (2022) 119612



ELSEVIER

Contents lists available at ScienceDirect

NeuroImage

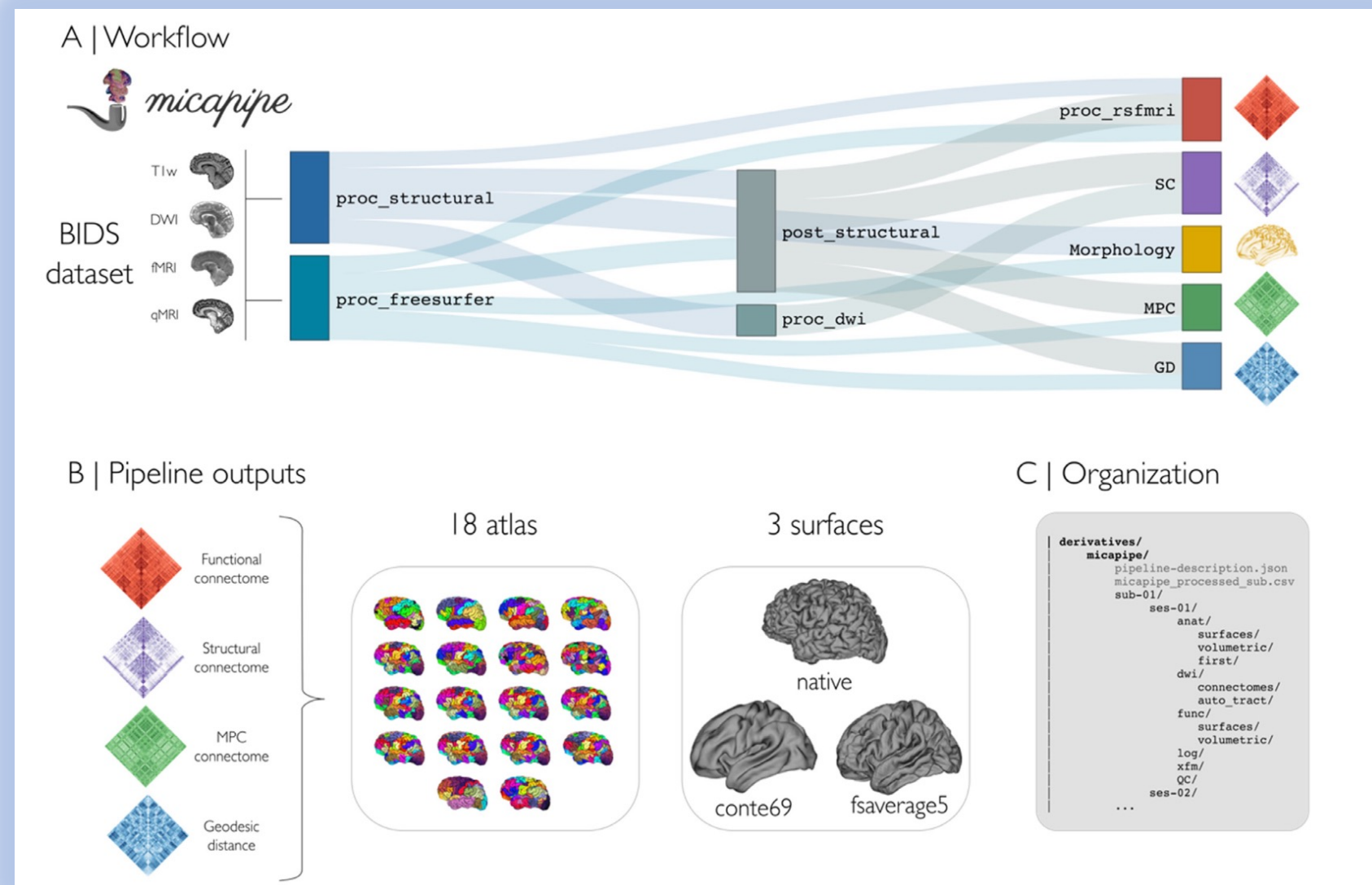
journal homepage: www.elsevier.com/locate/neuroimage



Micapipe: A pipeline for multimodal neuroimaging and connectome analysis



Raúl R. Cruces^{a,1,*}, Jessica Royer^{a,b,1,*}, Peer Herholz^c, Sara Larivière^a, Reinder Vos de Wael^a, Casey Paquola^{a,i}, Oualid Benkarim^a, Bo-yong Park^{a,d,e}, Janie Degré-Pelletier^f, Mark C. Nelson^g, Jordan DeKraker^a, Ilana R. Leppert^g, Christine Tardif^g, Jean-Baptiste Poline^g, Luis Concha^h, Boris C. Bernhardt^a





Standardi

Power Srls



SWANe

**Standardized Workflow for Advanced Neuroimaging
in Epilepsy**

USER MANUAL

Rev.	Date	Author
1.0	14/04/2023	Agostino Arcasensa
2.0	10/06/2023	Agostino Arcasensa
2.1	30/06/2023	Agostino Arcasensa
2.2	08/08/2023	Agostino Arcasensa

1

Power ICT s.r.l.s.

Tel. 0971 64100 Fax 0971 64047 - C.F. e P.IVA 01946770763

Via del Seminario Maggiore 115, 85100 Potenza (PZ) - c/o Centro Servizi Impresa Soc. Coop.

Fully automatic home-made script, 4-5 h

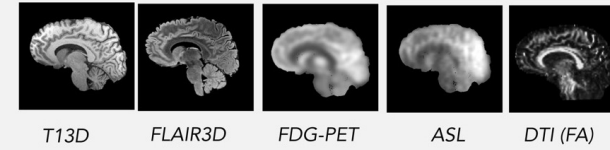
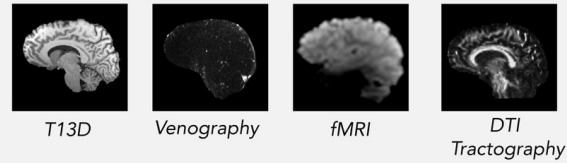


SWANe

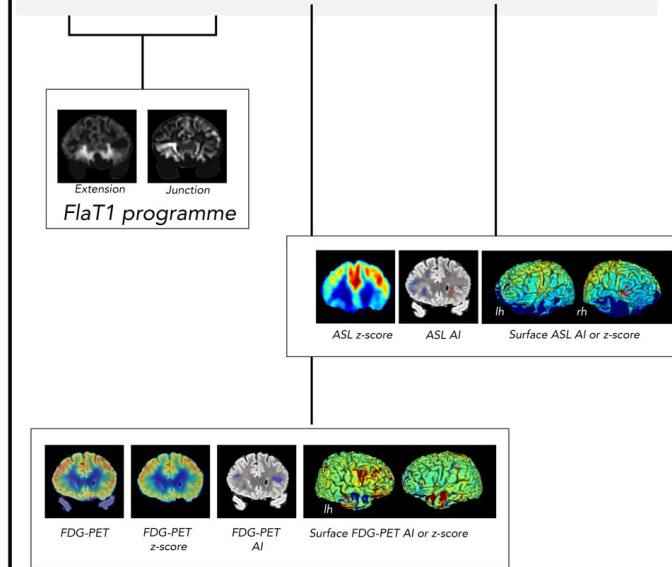
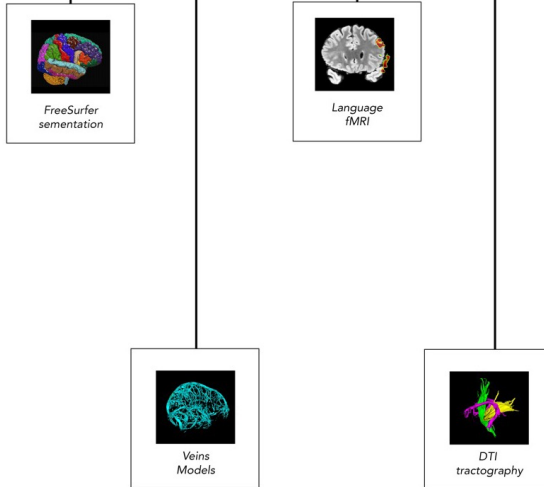
Structural Workflow

Morpho-Functional Workflow

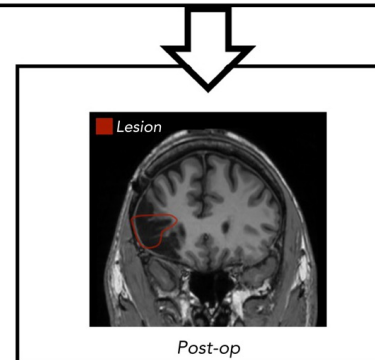
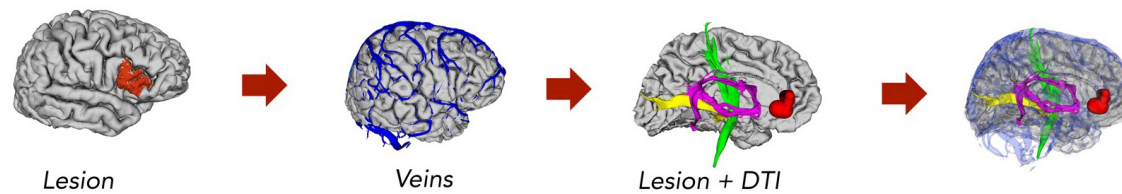
Input



Process



Output



3DSlicer





File Tools Help

Home

Welcome to SWANe!

SWANe (Standardized Workflow for Advanced Neuroimaging in Epilepsy) is a graphic tools for modular neuroimaging processing. With SWANe you can easily import and organize DICOM files from multiple sources, generate a pipeline based on available imaging modalities and export results in a multimodal scene.

SWANe does NOT implement processing software but integrates in a user-friendly interface many external applications, so make sure the check the following dependencies.

SWANe is not meant for clinical use!

External mandatory dependencies:

- ✓ dcm2niix detected (v1.0.20210317)
- ✓ FSL detected (6.0.5.2:dc6f4207)

External recommended dependencies:

- ✓ FreeSurfer detected (7.3.2). Matlab Runtime is not installed ([registration instruction](#))
- ✓ Slicer detected

External optional dependencies:

- ✓ Graphviz detected

SWANe, open page. Check for dependencies

SWANe - Standardized Workflow for Advanced Neuroimaging in Epilepsy

File Tools Help

Home × pt_260

Data load Workflow execution Results export

- ✓ **3D T1w**
EEG-fMRI_448^EEG-fMRI_448-MR-ORIG 3D SagT1 new accFac1.5: 312 images
- ✓ **3D Flair**
EEG-fMRI_448^EEG-fMRI_448-MR-Sag CUBE flair new: 260 images
- ✗ **Post-contrast 3D T1w**
- ✓ **Venous MRA - Phase contrast**
EEG-fMRI_448^EEG-fMRI_448-MR-3D Venosa PC: 480 images
- ✗ **Venous MRA - Second phase**

Scan DICOM folder

EEG-fMRI_448^EEG-fMRI_448-MR-Sag CUBE flair new: 260 images

EEG-fMRI_448^EEG-fMRI_448-MR-3D Venosa PC: 480 images

EEG-fMRI_448^EEG-fMRI_448-MR-ORIG 3D SagT1 new accFac1.5: 312

EEG-fMRI_448^EEG-fMRI_448-MR-Ax DTI 64 2.5mmiso mB1000: 338

EEG-fMRI_448^EEG-fMRI_448-MR-3D ASL: 36 images

SWANe, upload DICOM files

SWANe - Standardized Workflow for Advanced Neuroimaging in Epilepsy

File Tools Help

Home × pt_260

Data load Workflow execution Results export

Structural Workflow

✓ Morpho-Functional Workflow

Workflow preferences

Generate SWANe Workflow

Execute SWANe Workflow

SWANe, select workflow

Workflow settings

- ✓ FreeSurfer analysys
- ✓ FreeSurfer hippocampal subfields
- ✓ Asymmetry Index map for ASL and PET
- ✓ FlaT1 analysis
- DTI tractography

Tractography settings

- ✓ Arcuate Fasciculus
- Acoustic Radiation
- Anterior Thalamic Radiation
- Cingulum subsection : Dorsal
- Cingulum subsection : Peri-genual
- Cingulum subsection : Temporal
- ✓ Corticospinal Tract
- Frontal Aslant
- Fornix
- Inferior Longitudinal Fasciculus
- Inferior Fronto-Occipital Fasciculus
- Middle Longitudinal Fasciculus
- ✓ Optic Radiation
- Superior Thalamic Radiation
- Uncinate Fasciculus
- Vertical Occipital Fasciculus

Save preferences

Discard changes

fMRI - 0

Task A name Task B name

Task duration (sec) Rest duration (sec)

TR (sec) Number of EPI runs

Block design Slice timing

Delete start volumes Delete end volumes

fMRI - 1

Task A name Task B name

Task duration (sec) Rest duration (sec)

TR (sec) Number of EPI runs

Block design Slice timing

Delete start volumes Delete end volumes

fMRI - 2

Task A name Task B name

Task duration (sec) Rest duration (sec)

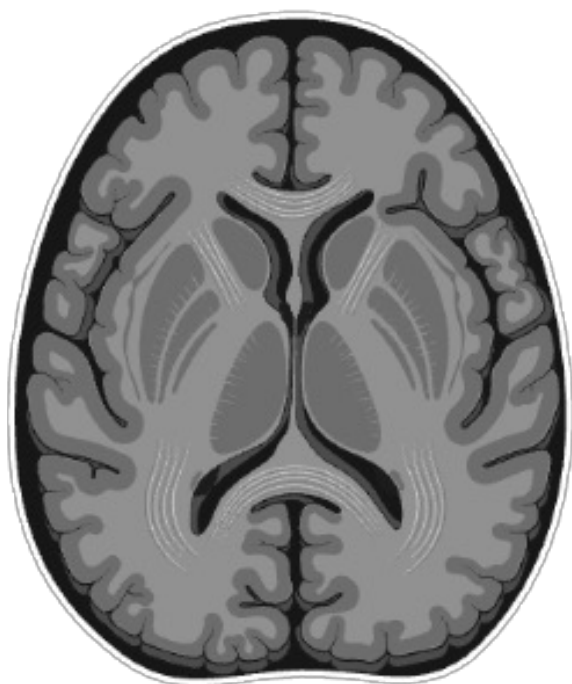
TR (sec) Number of EPI runs

Block design Slice timing

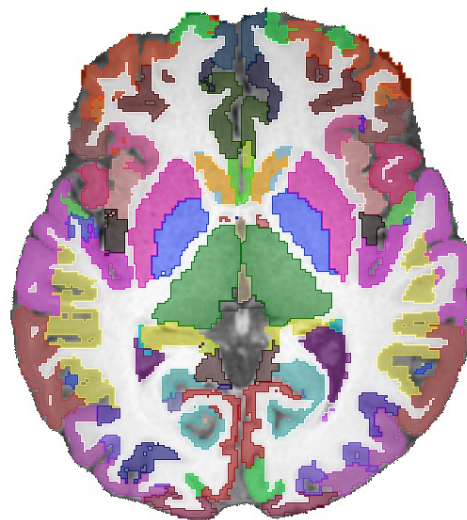
Delete start volumes Delete end volumes

SWANe, set preferences

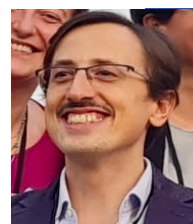




Input: T13D

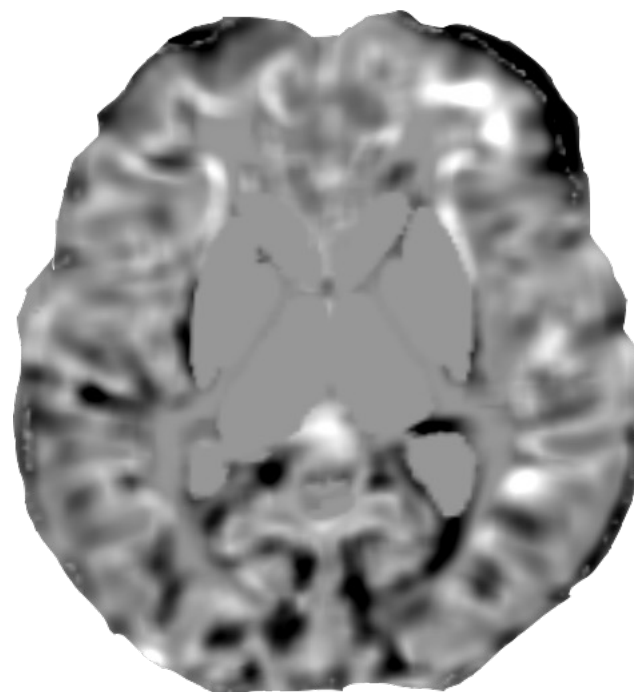


FS segmentation+ Amy/Hyppo Segmentation
Measures of thickness/volumes/surface/
cortical and subcortical

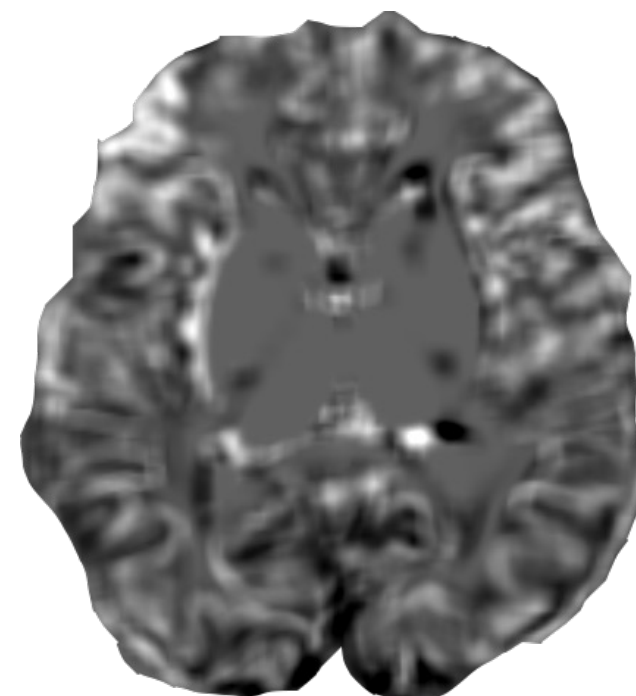


FlaT1 analysis

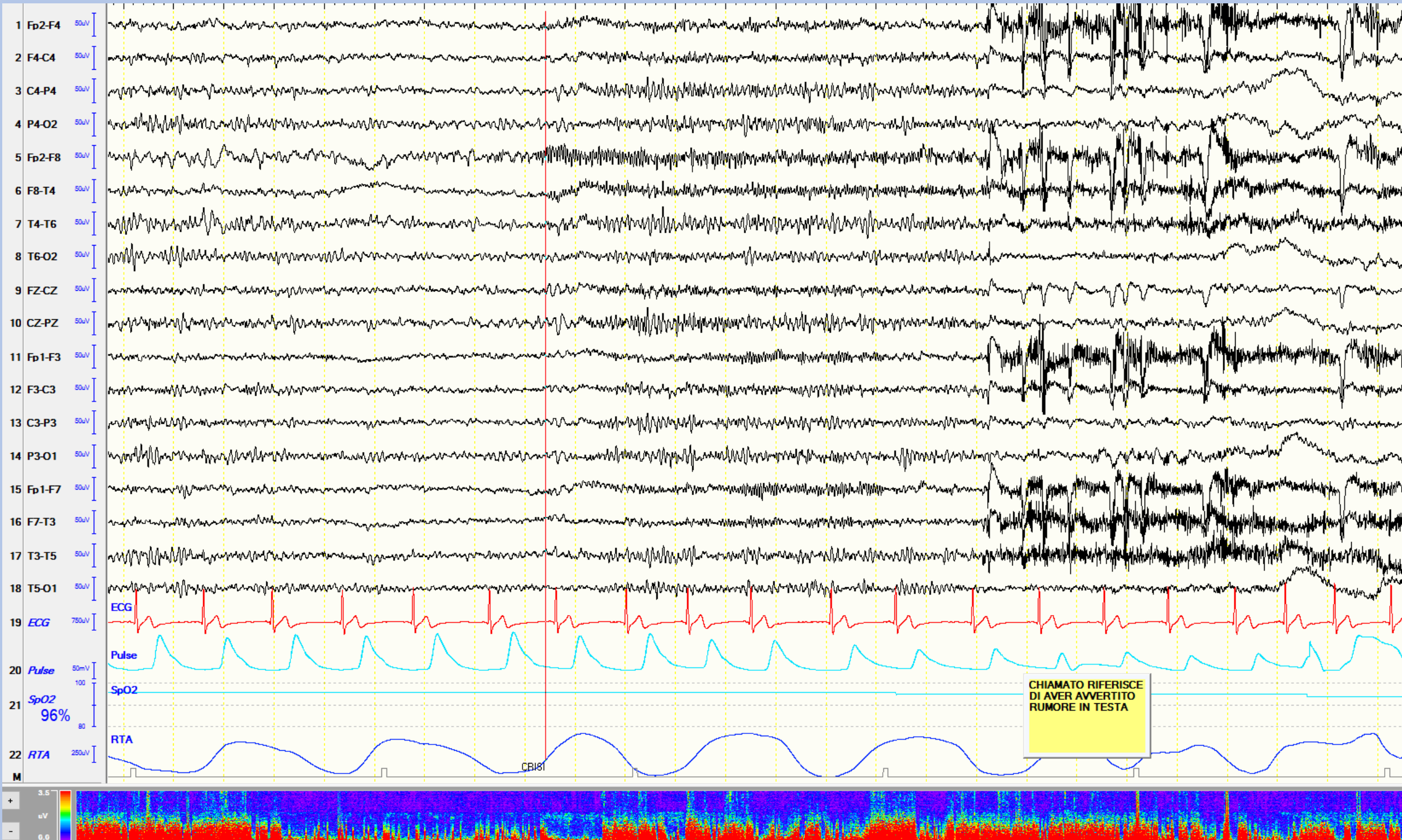
Junction map Z score

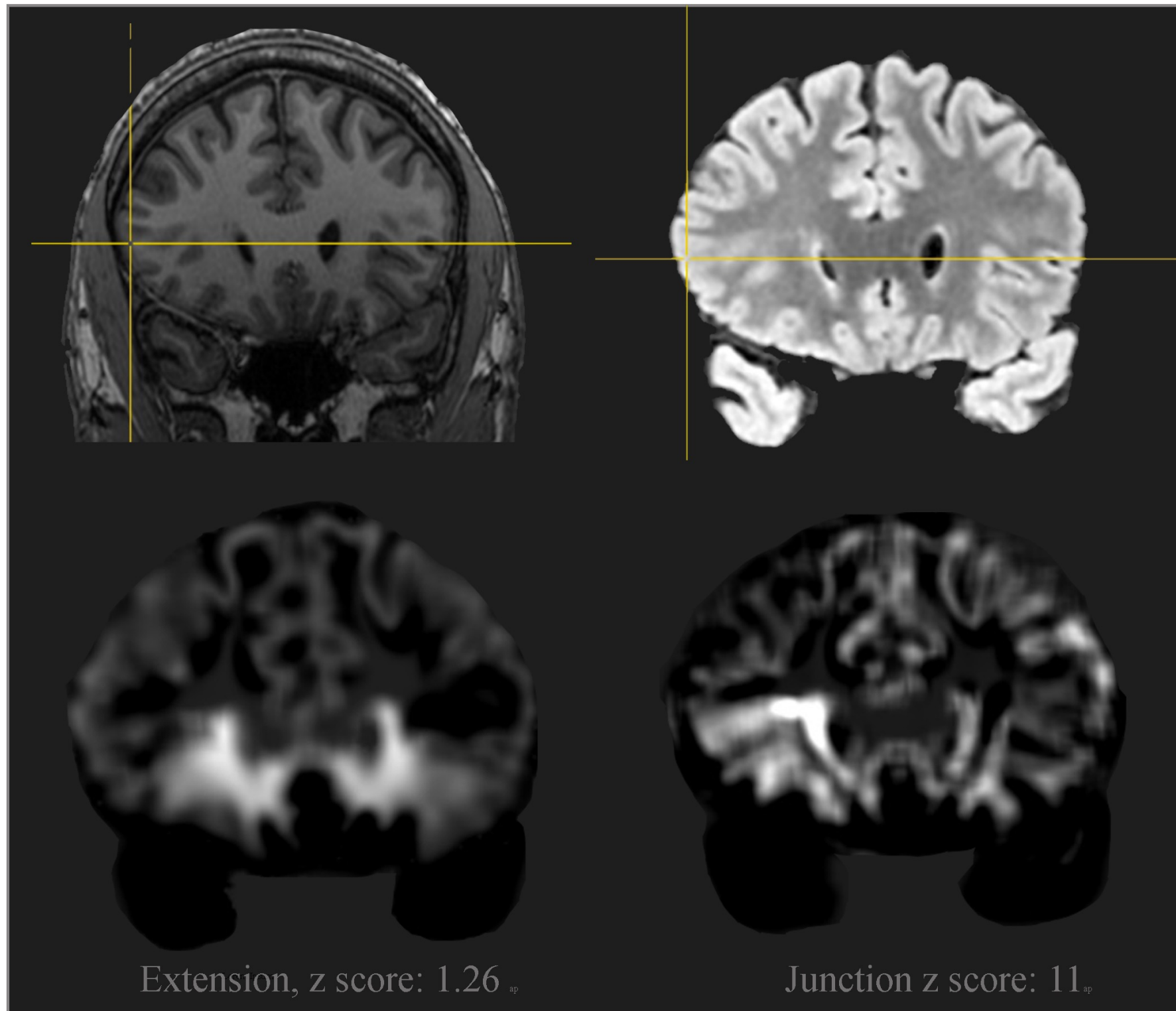


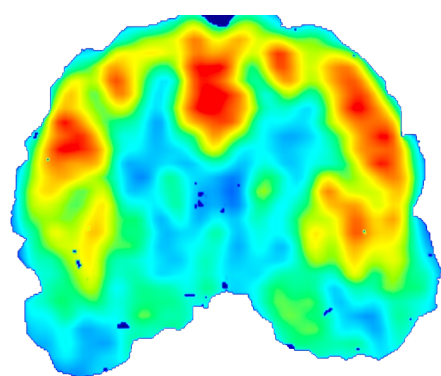
extension map, Z score



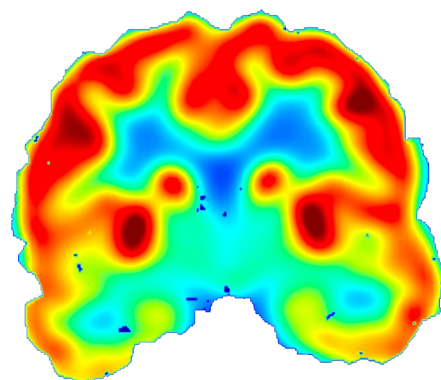
FA, 29 anni Epi F destra



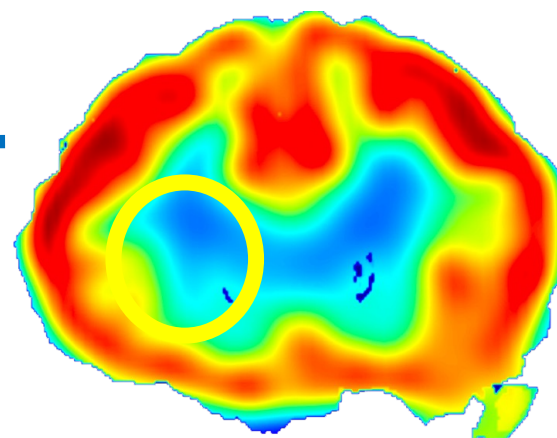




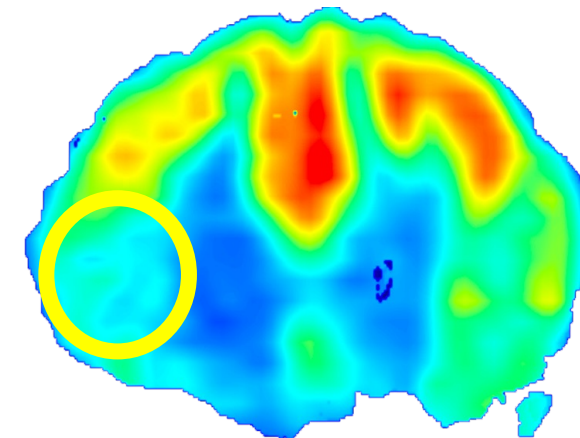
ASL



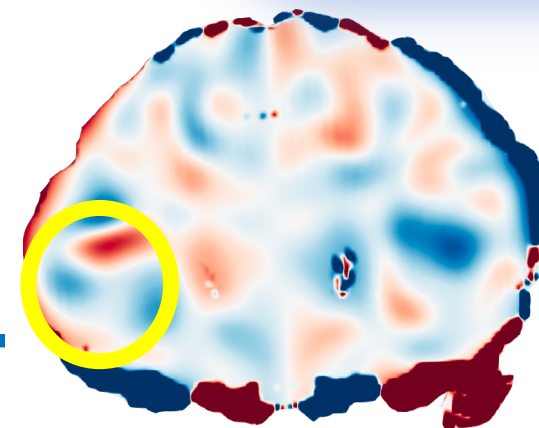
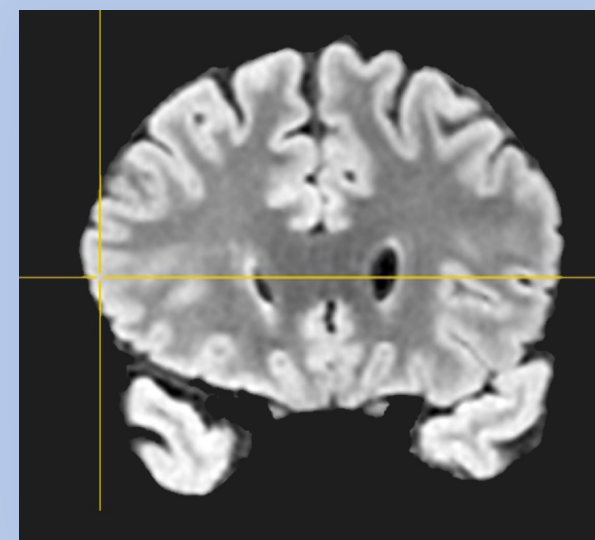
Fdg-PET



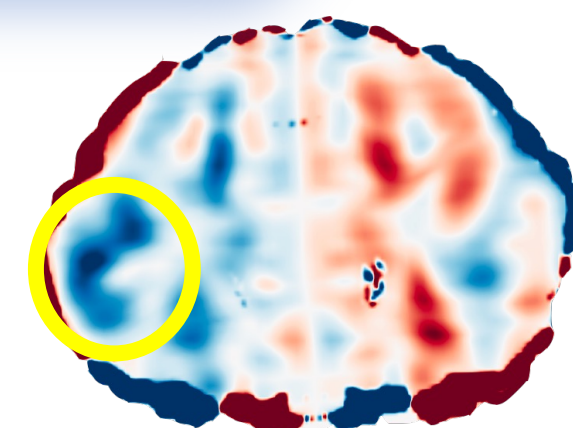
Fdg-PET, Z-score, -0.03



ASL, Z-score, -1

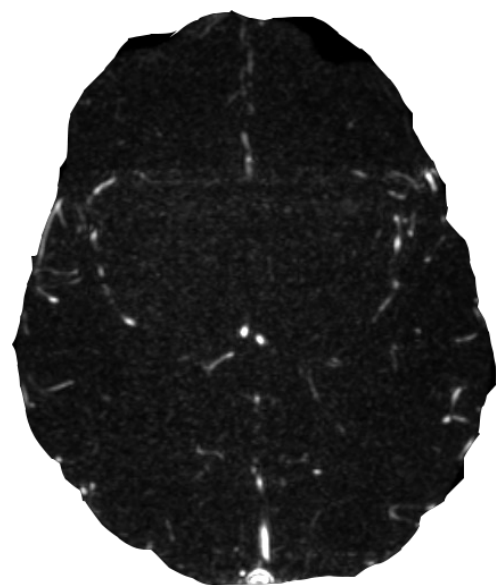


Fdg-PET, AI (-1 to 1)=-0.09

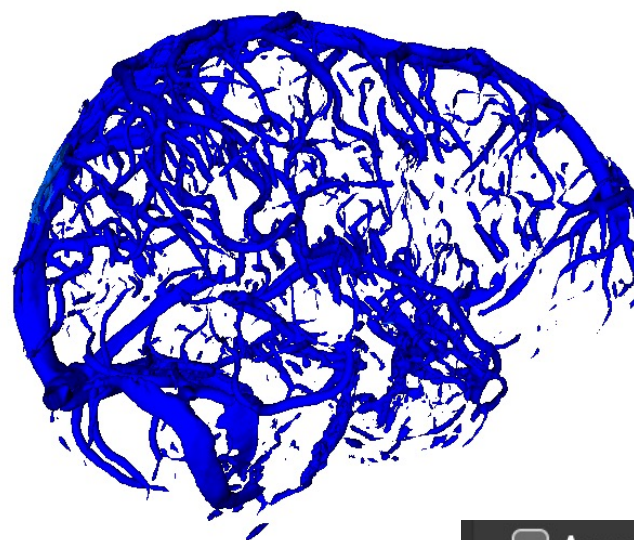
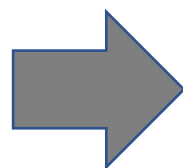


ASL, AI (-1 to 1)=-0.28

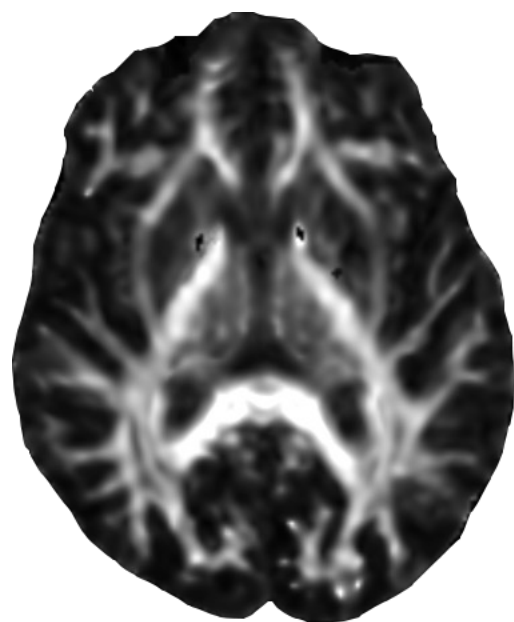
AI: $(R-L)/(R+L)$



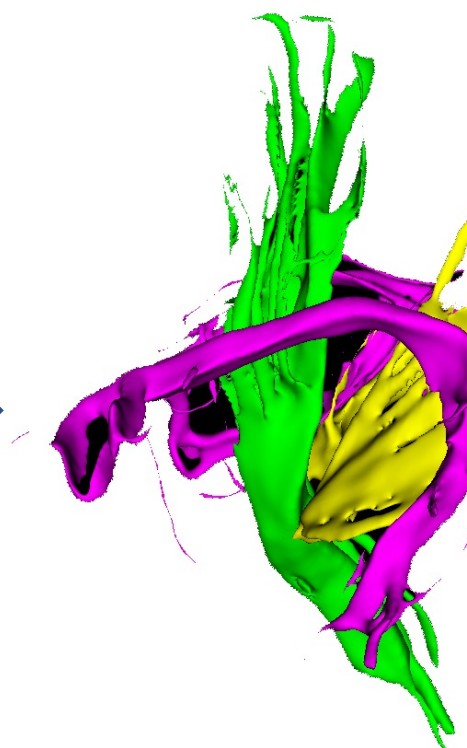
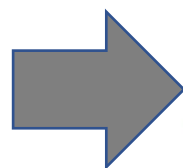
AngioRM venosa



Modello Vene

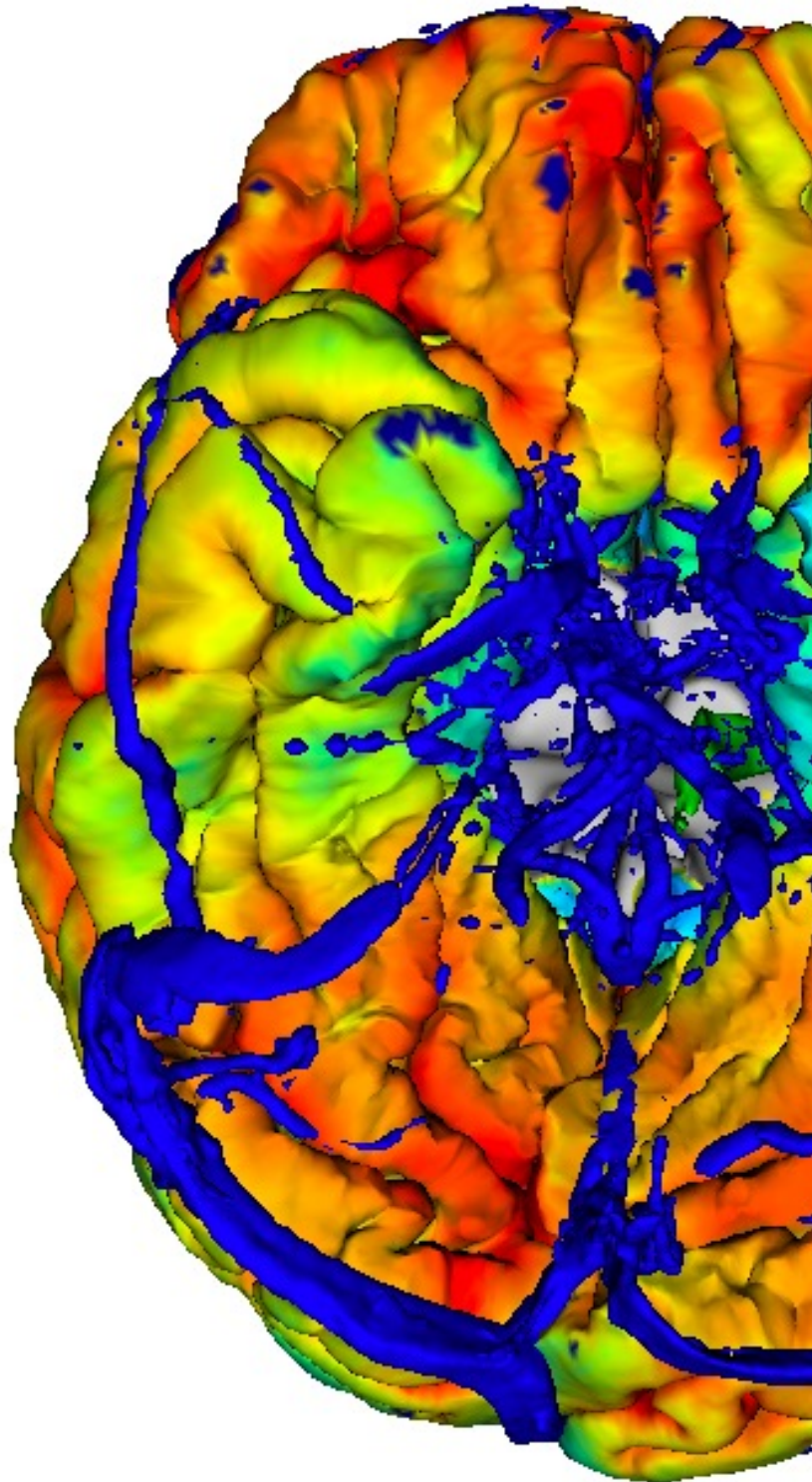


DTI
(Valori di FA, MD)

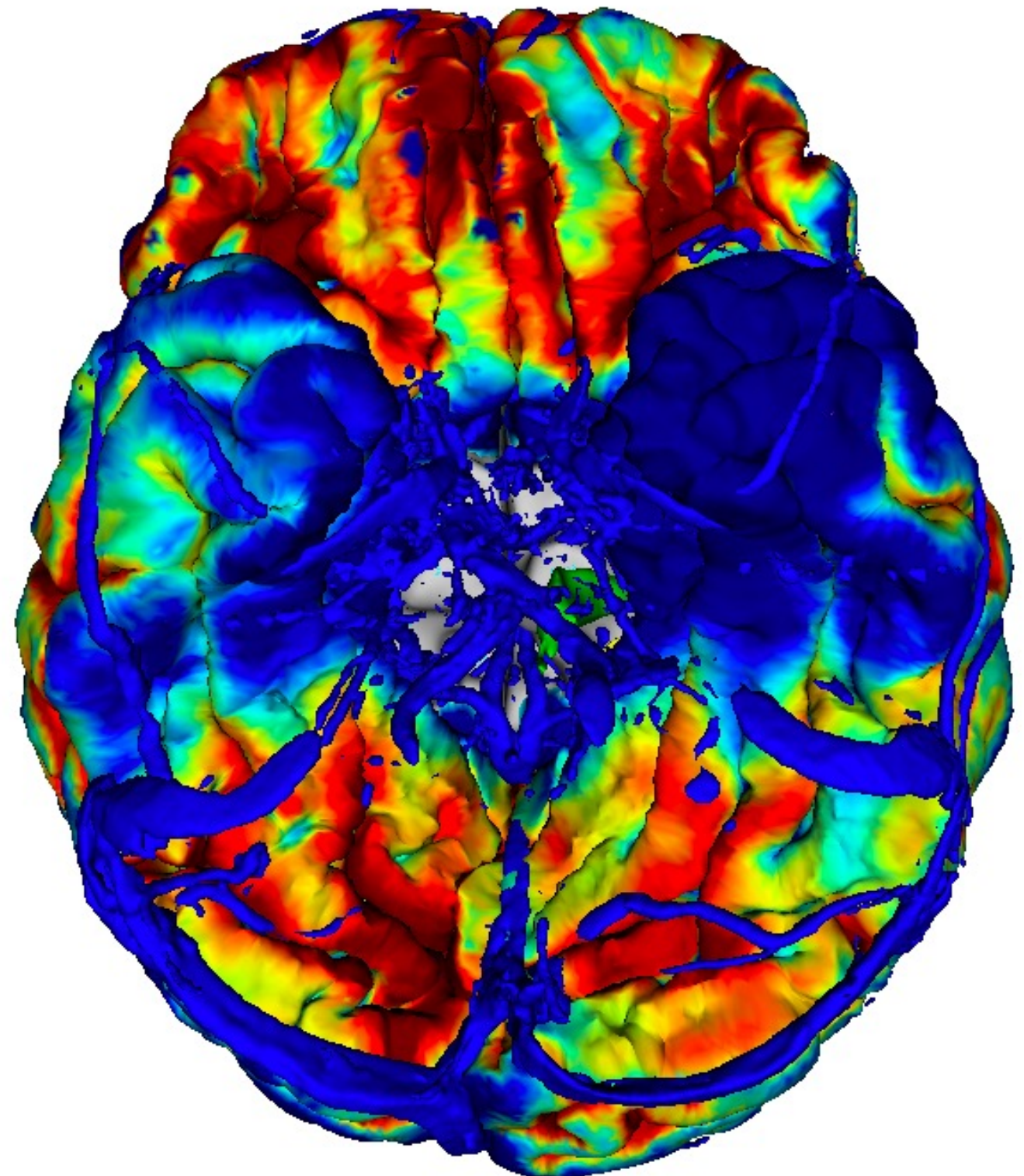


Modello Fasci

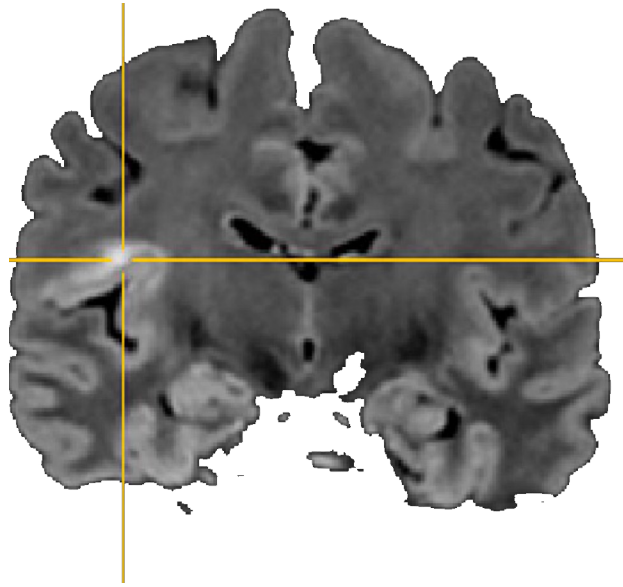
- Arcuate Fasciculus
- Acoustic Radiation
- Anterior Thalamic Radiation
- Cingulum subsection : Dorsal
- Cingulum subsection : Peri-genual
- Cingulum subsection : Temporal
- Corticospinal Tract
- Frontal Aslant
- Fornix
- Inferior Longitudinal Fasciculus
- Inferior Fronto-Occipital Fasciculus
- Middle Longitudinal Fasciculus
- Optic Radiation
- Superior Thalamic Radiation
- Uncinate Fasciculus
- Vertical Occipital Fasciculus



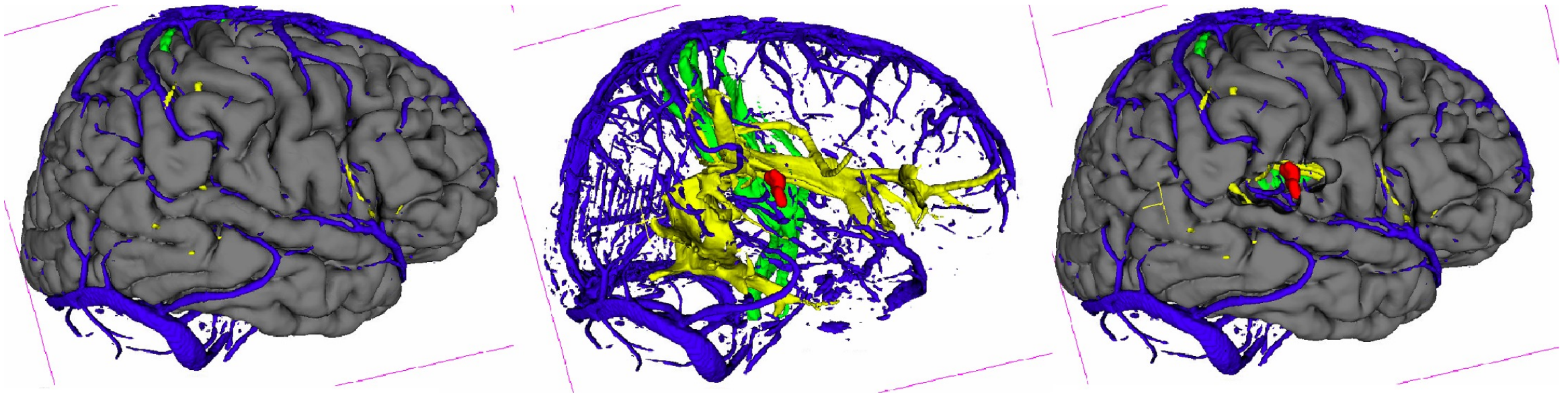
Epi T sinistra cripto, PET



Epi T sinistra cripto, PET Z score



- Multidisciplinary case discussion
neurologists, neuroradiologists and neurosurgeons
- Decision of the best surgical approach, virtual surgery



■ lesion

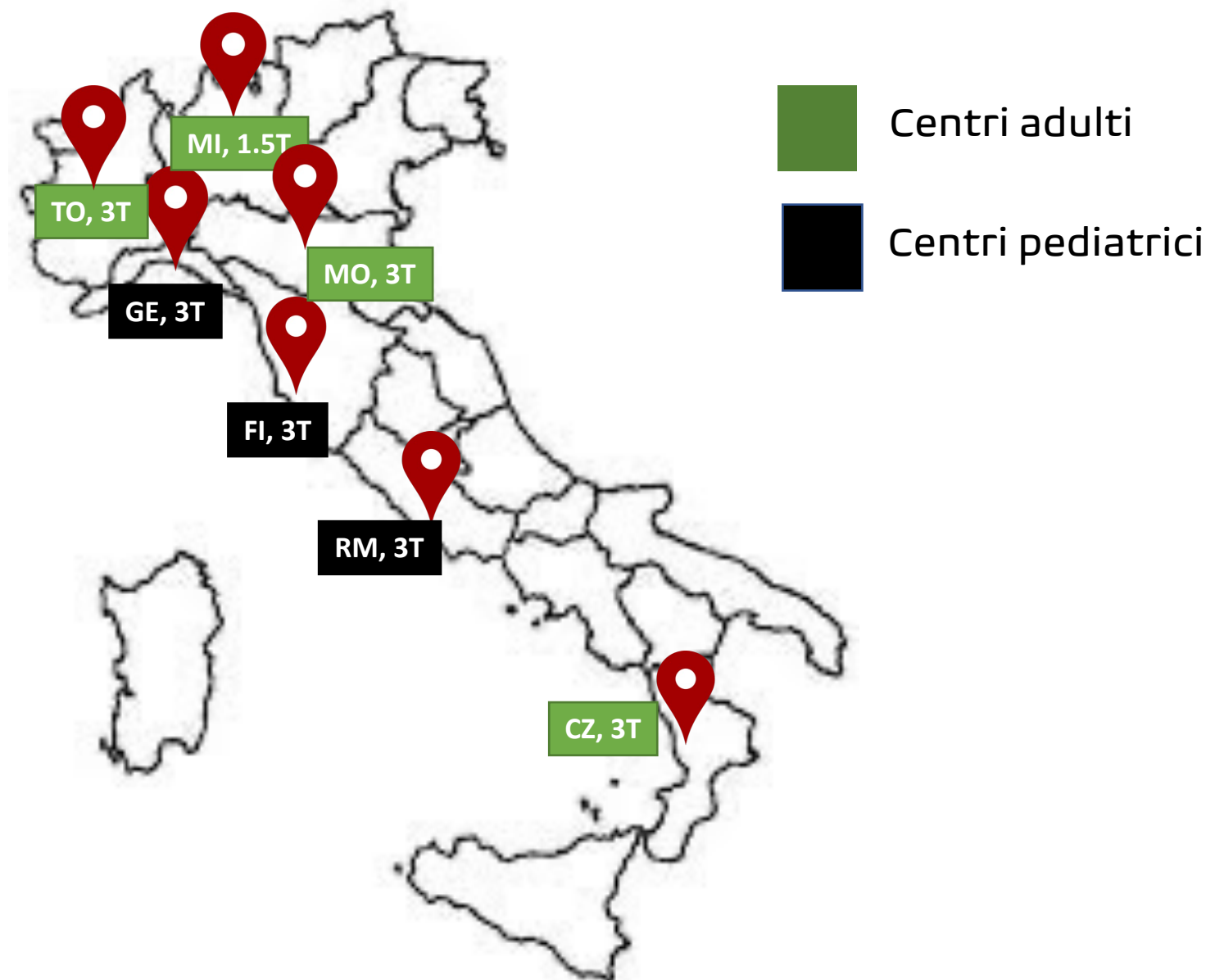
■ optic radiation

■ corticospinal tract

■ arcuate fasciculus



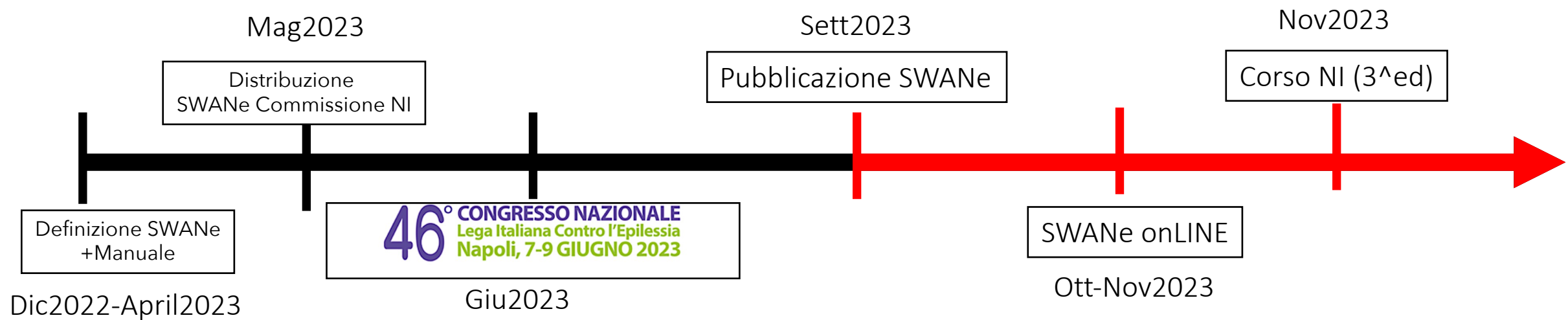
INSTALLAZIONE DI SWANE



28 Pazienti operati

16 bambini, 12 adulti (RM, GE, MO, MI, TO)

- Analisi completata in LOCO da personale con expertise e senza
- Pipeline completata in tutti i pazienti
- Esportazione dei risultati completata in tutti i pazienti
- Valutazione qualitativa dei risultati:
Concordanza con resezione chirurgica ispezionata in 10 casi, concordante 10/10



**2° CORSO PRATICO RESIDENZIALE
IMAGING AVANZATO NELLO STUDIO DELL'EPILESSIA**
Utilizzo delle tecniche avanzate per la localizzazione della zona epilettogena

Bologna - Relais Bellaria Hotel & Congressi
17 - 20 novembre 2023

 **LICE**
Lega Italiana Contro l'Epilessia



Con il Patrocinio di



annavaudano@gmail.com

domenicotortora@gmail.com

Imaging avanzato in chirurgia epilessia

- Ad oggi, molto (se non esclusivamente) utilizzato alla identificazione della zona lesionale (ZE) nelle epilessie focali
- Concentrato sulle anatomiche T1 e FLAIR (sMRI), meno sul multimodale (pipeline complesse, time consuming)
- Complessivamente, metodi con discreta sensibilità e specificità **se affiancato a CVA**
- Alcuni toolbox sono facili e non richiedono expertise
- Open source software (eccetto MAP18) (con Vantaggi/Svantaggi)
- Pochi tools CE/FDA approved

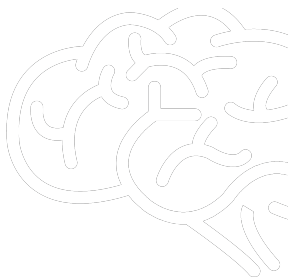
SWANe

- integra diverse modalità di imaging (funzionale, strutturale e metabolico) incrementando la sensibilità e specificità delle singole metodiche
- Permette di ottenere una ricostruzione 3D dell'output delle diverse immagini consentendo una migliore definizione dei rapporti della lesione con le aree eloquenti e una più efficace pianificazione chirurgica
- È automatico, time/error saving

Grazie a tutti per l'attenzione



- Prof. Stefano Meletti
- Dr. Anna Elisabetta Vaudano
- Dr. Simona Scolastico
- Dr. Niccolò Biagioli
- Dr. Elisa Micalizzi
- Dr. Francesca Talami
- Dr. Alice Ballabeni
- Dr. Alessia Casarini





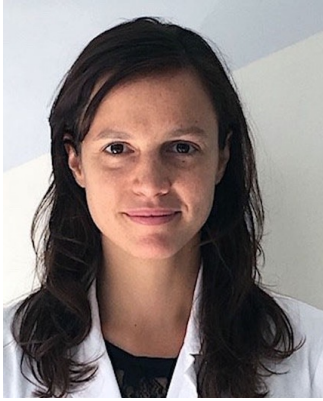
2021-2024



Grazie a tutti per l'attenzione



Laura Mirandola



Silvia Morbelli



Maria Eugenia Caligiuri



Ferruccio Panzica



Matteo Lenge



Francesco Cardinale



Camilla Rossi Espagnet



Massimo Caulo



Carmen Barba



Maurilio Genovese



Anna E. Vaudano



Domenico Tortora



Grazie a Power ICT



&

Alice Ballerini