Tractographie des nerfs crâniens & de la moelle spinale : Développement pour l'Anatomie chirurgicale

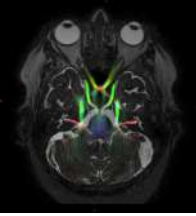
Timothée JACQUESSON [1,2,3]

9 mai 2022

[1] Laboratoire CREATIS, CNRS UMR5220, Inserm U1206, INSA-Lyon
[2] Unité de chirurgie des tumeurs de la base du crâne, CHU Lyon
[3] Laboratoire d'Anatomie Rockefeller, Université Lyon 1

Hospices Civils de Lyon

CREATIS



Plan

Question clinique et rationnel

1. Tractographie des nerfs crâniens
   a. Revue et optimisation
   b. Série clinique
   c. Full brainstem and CN tractography
2. Tractographie de la moelle spinale
   a. Revue
   b. Full cervical cord tractography
3. Anatomie chirurgicale
   a. Key points
   b. Fibres blanches
   c. Pyramide pétreuse & Variations anatomiques
   d. Stéréoscopie / photogrammétrie
4. Perspectives
   a. T2 HR
   b. Signature tumorale
   c. Automatisation / Apprentissage
   d. Différenciation des faisceaux spinaux

CREATIS

Time line

- **Thèse** de Médecine *EEA vers PA*

- Formation Mrtrix3/Trackvis
- VIP optimisation
- Accord CPP (12 juillet 2016)

- Début *PhD*

- ROI sur T2-ODF
- *Tracto series*
- **AHU4**

- **Mobilité 2** Tours
- *SC trato Review*
- CNU Anatomie

- *Full spine tracto*
- Signature tumorale

- Caractérisation tumorale
- *Spinal cord WM*

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

- Tests préliminaires tractographie
- **AHU1**

- Début TRACNER
- *Review CN tracto*
- **AHU3**

- **Mobilité 1** Pitt
- ISMRM
- DSI Studio
- *Full tracto*

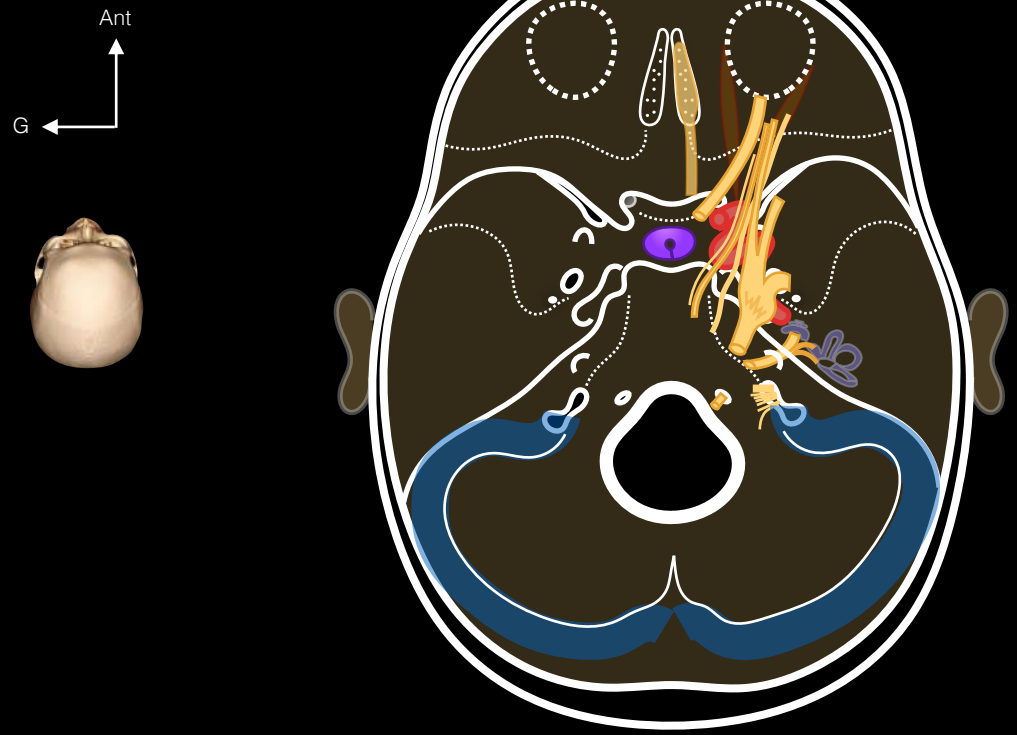
- **MCU Anatomie**
- Filtrage / entropie / PdV

- IRM T2 HR
- Segmentation automatisée
- **HDR ?**

- Envoi dossier CPP
- Inclusion 1^{iers} patients
- **AHU2**

CREATIS

Défi Clinique

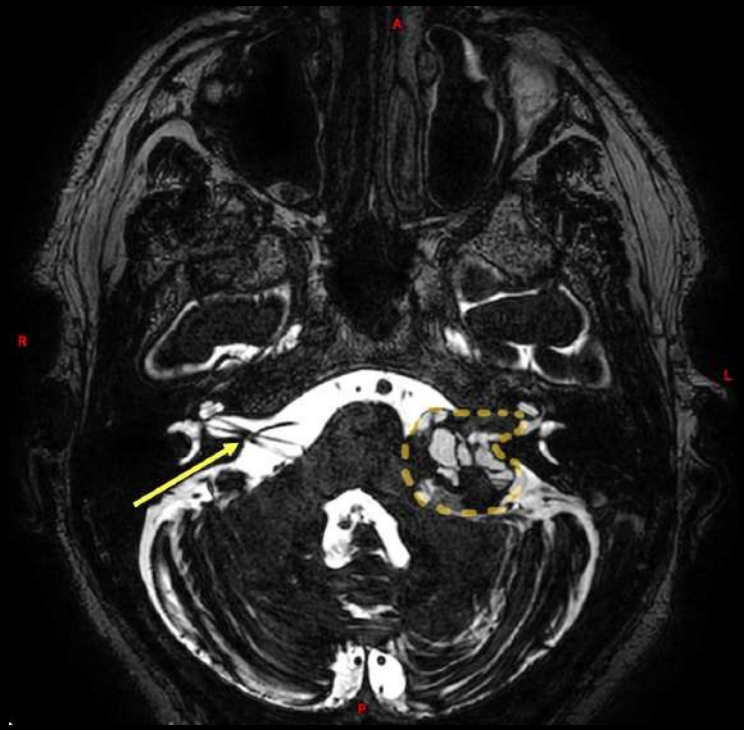


Un environnement **anatomique** complexe

Des rapports étroits avec les **nerfs crâniens** et les vaisseaux

Une chirurgie à risque de **séquelles neurologiques**

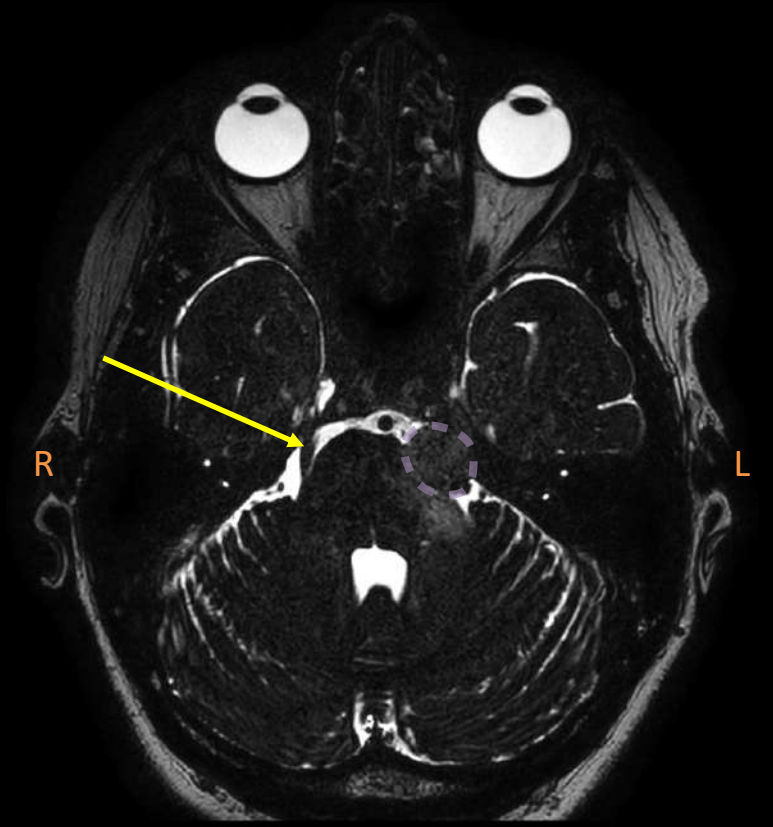
Limites de l'IRM



Personal data – T2 CISS cerebral MRI axial slice

L'IRM classique ne permet pas de visualiser les nerfs crâniens en condition tumorale

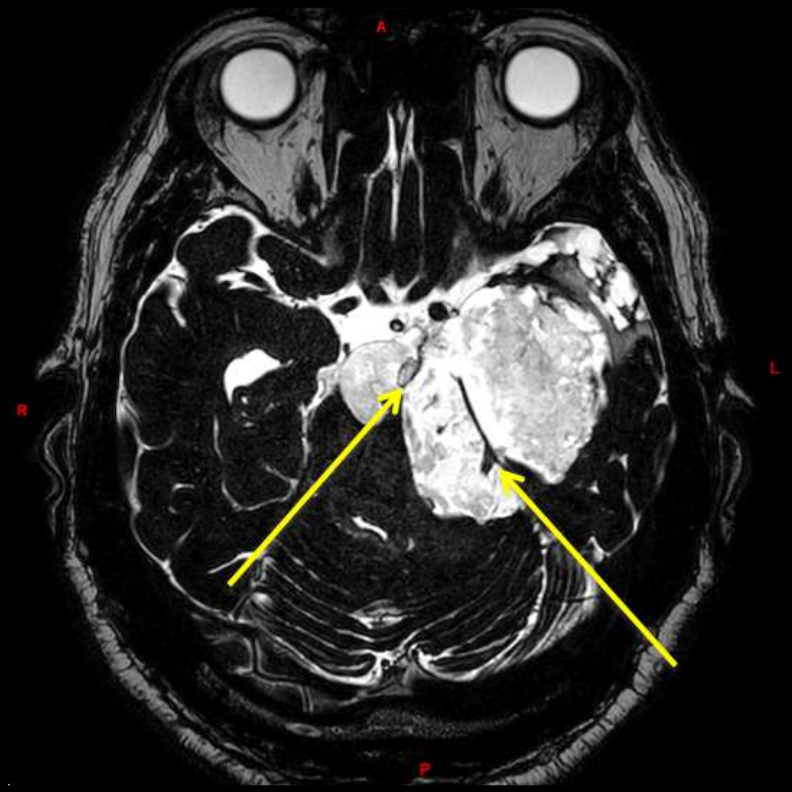
Limites de l'IRM



Personal data – T2 CISS cerebral MRI axial slice

L'IRM classique ne permet pas de visualiser les nerfs crâniens en condition tumorale

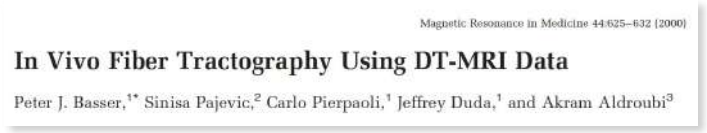
Limites de l'IRM

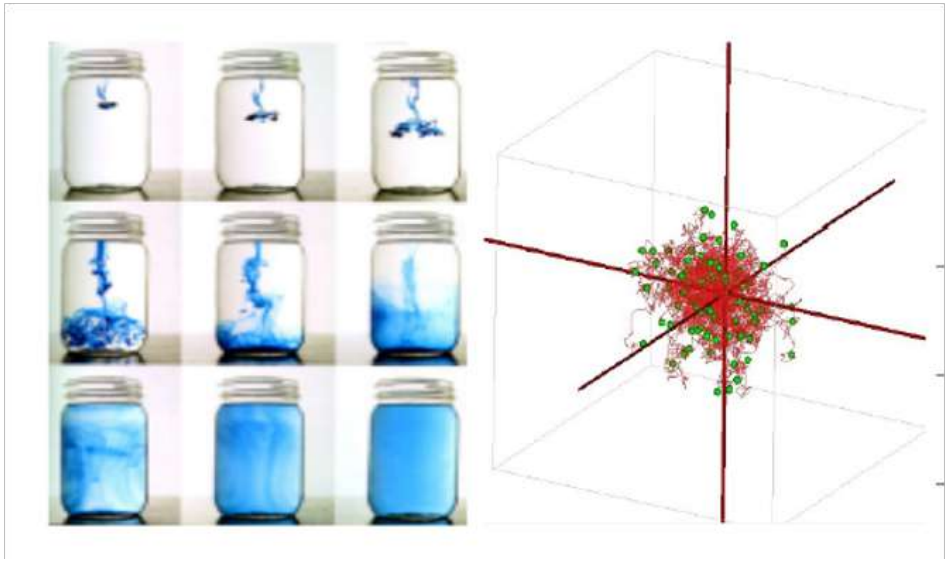


Personal data – T2 CISS cerebral MRI axial slice

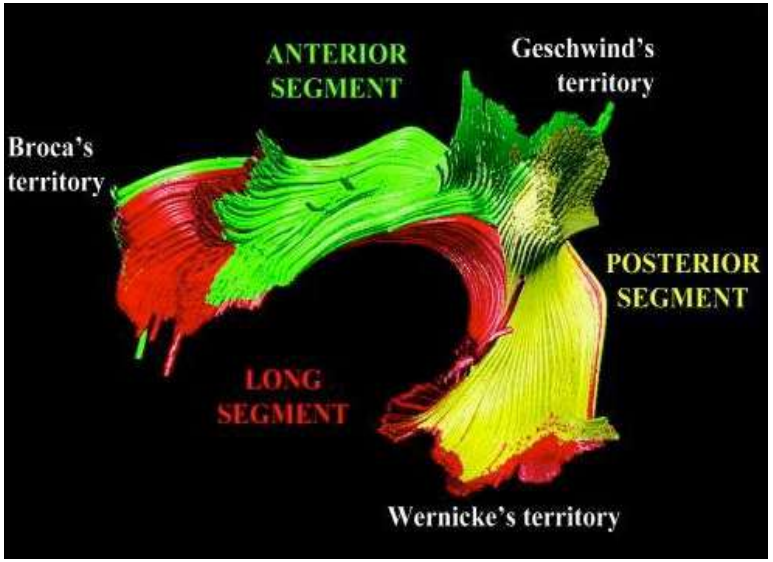
L'IRM classique ne permet pas de visualiser les nerfs crâniens en condition tumorale

Tractographie





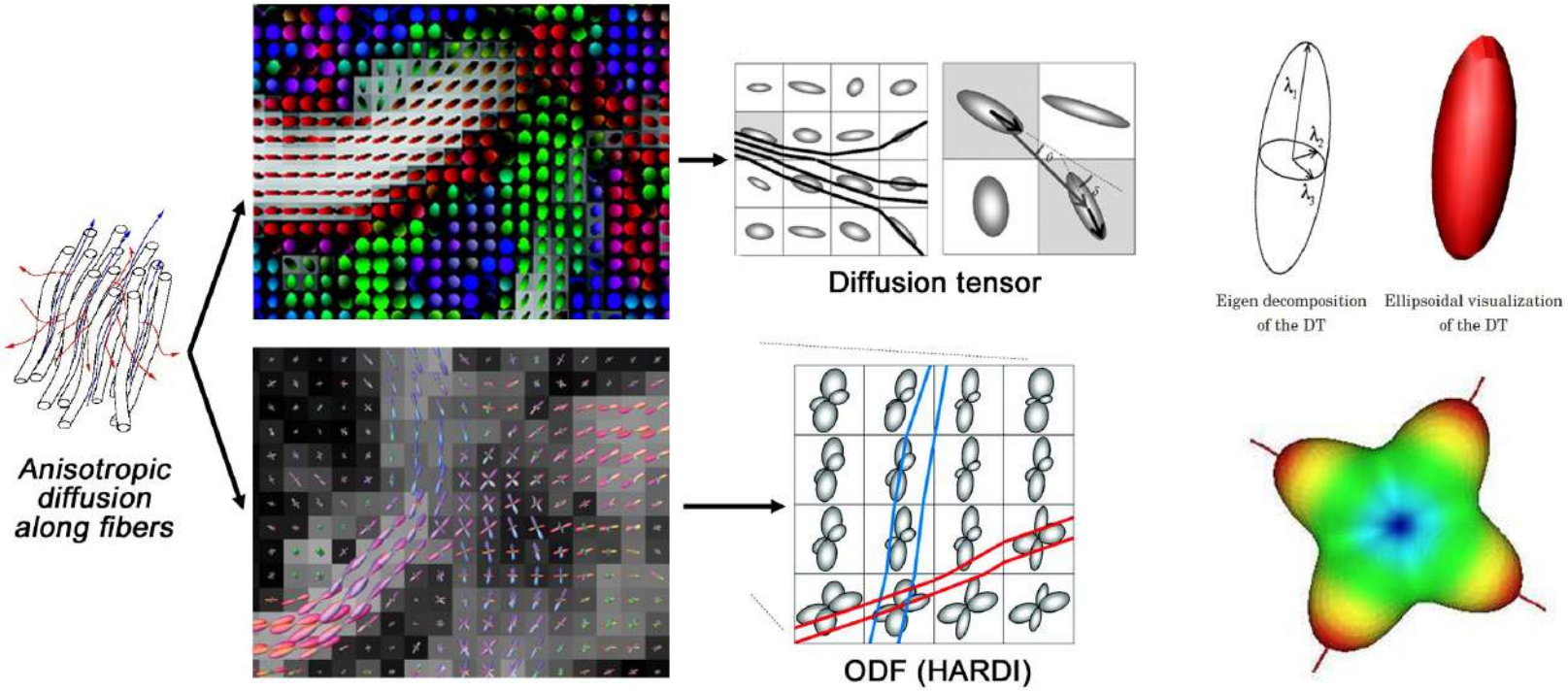
Descoteaux & Poupon, 2014



Catani et al, 2005

1. Détection de la diffusion préférentielle des molécules d'H20 le long des fibres
2. Reconstruction des fibres par algorithme mathématique

DTI vs ODF

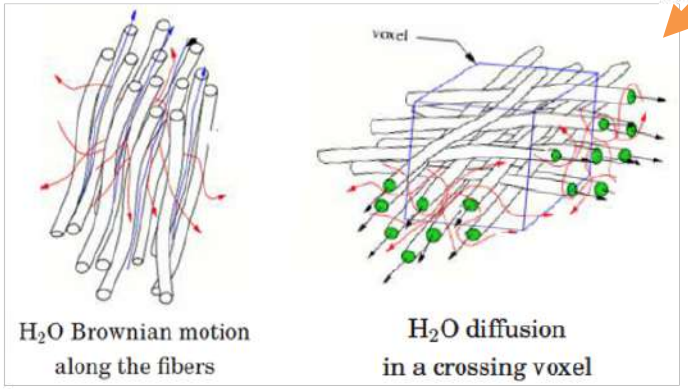


Adapted from Descoteaux & Poupon, 2014

Différents modèles de diffusion :

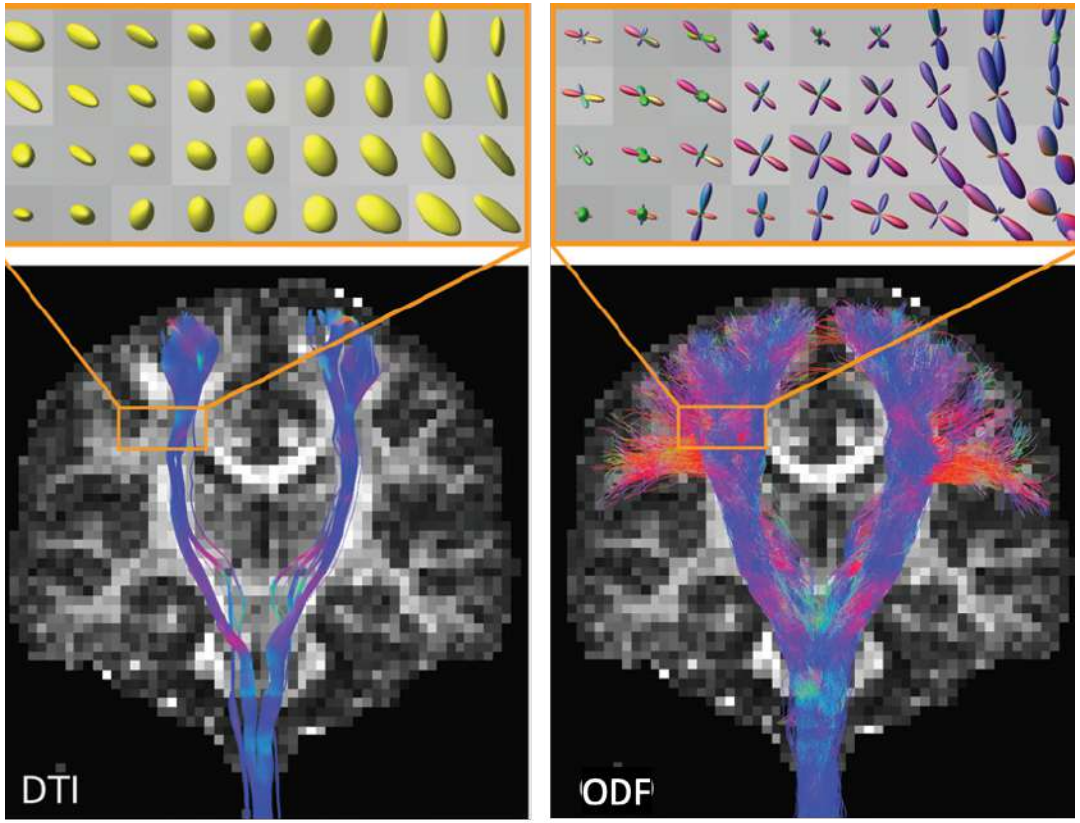
1. Tenseur de diffusion (DTI)
2. Fonction de Distribution de l'Orientation (ODF)

CSD -> ODF



Déconvolution sphérique contrainte
= Extraction de la probabilité d'orientation de la diffusion

DTI vs ODF

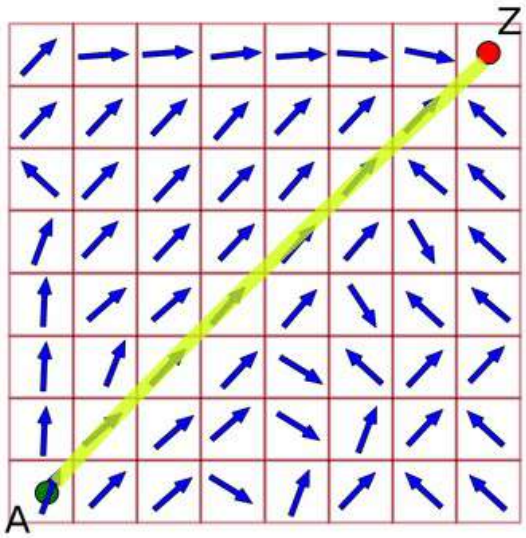


Farquharson et al. 2013

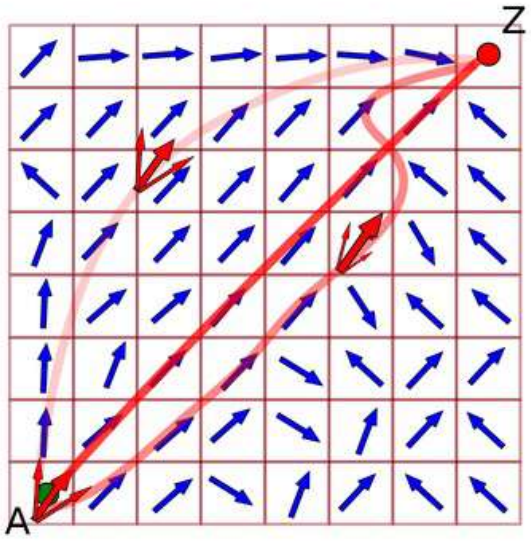
1 ou plusieurs directions de diffusion

Algorithme de reconstruction

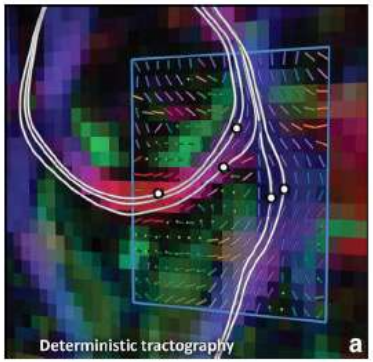
(i)Deterministic



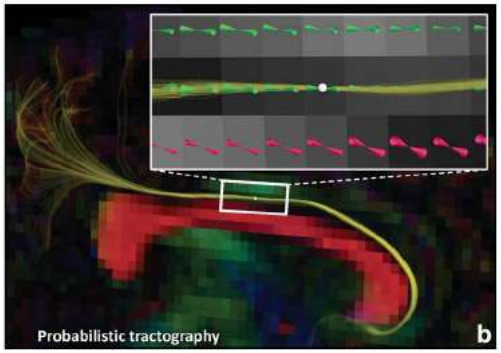
(ii)Probabilistic



Garyfallidis et al., 2012

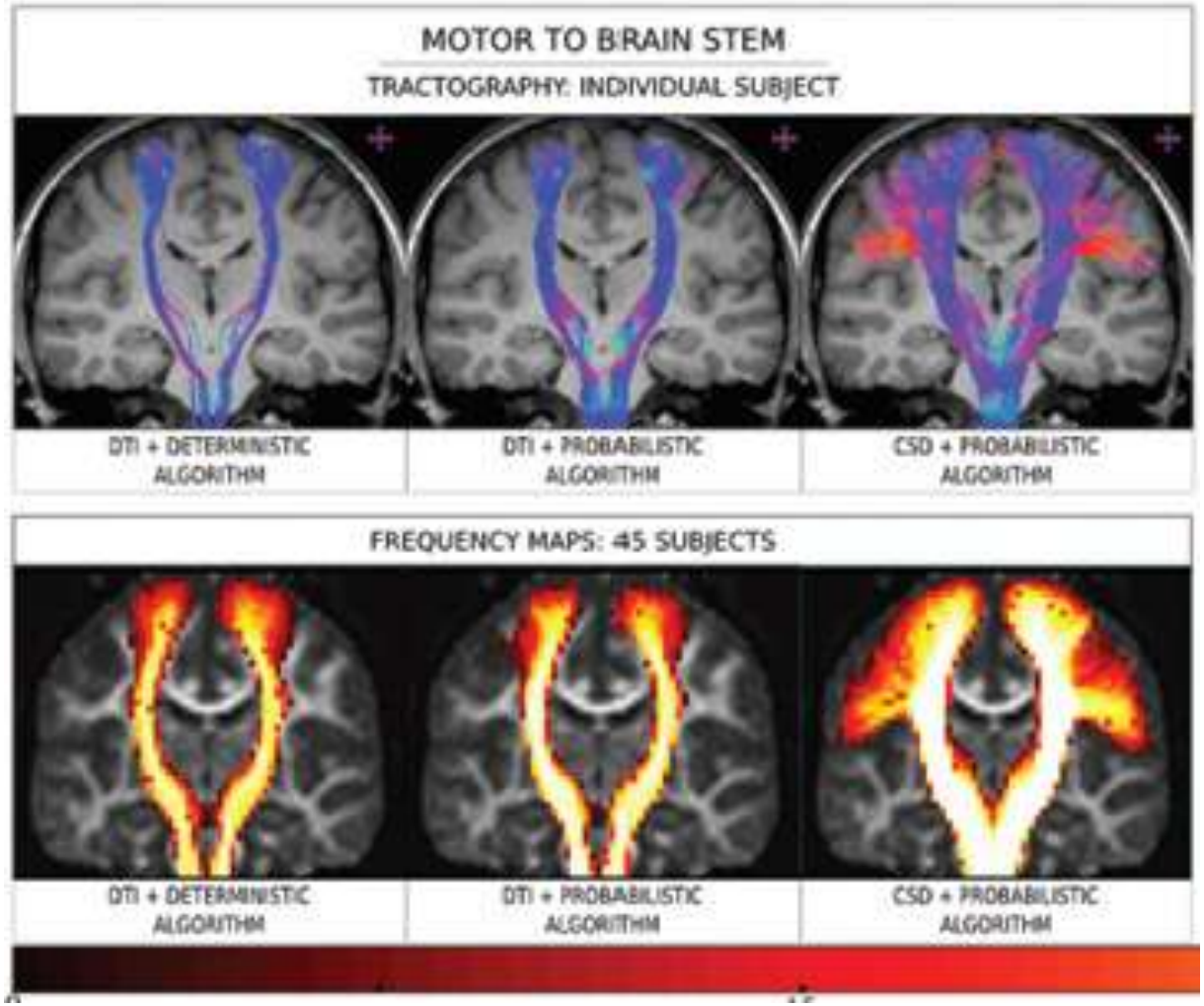


Tournier et al., 2011



Tournier et al., 2011

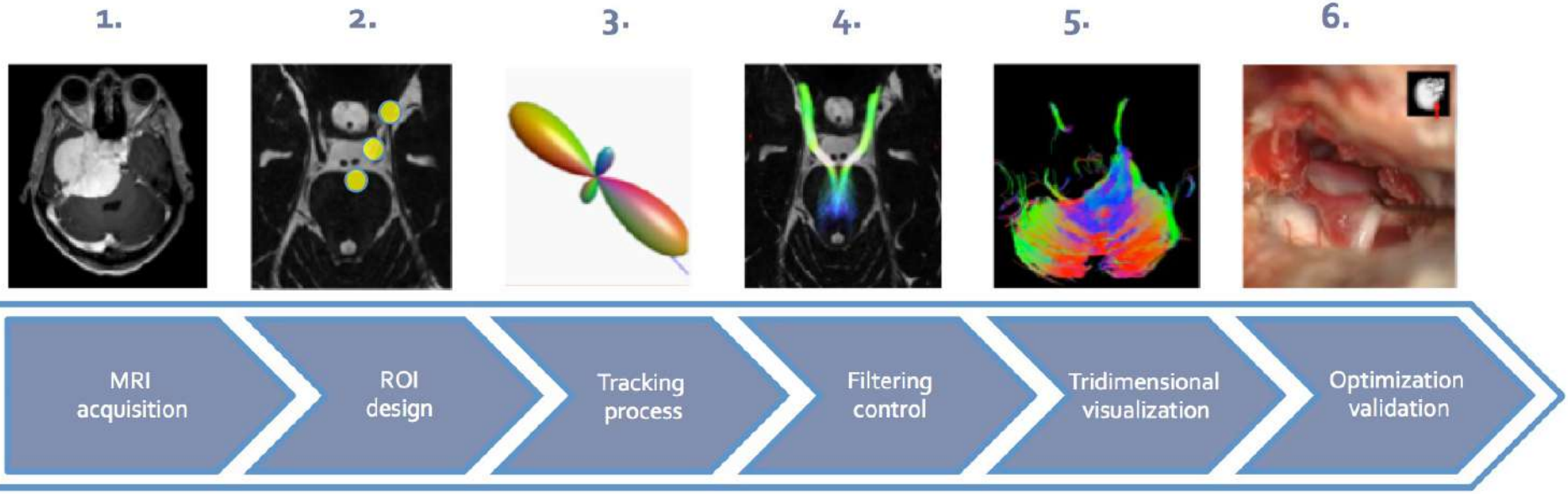
Modèle & Algorithme



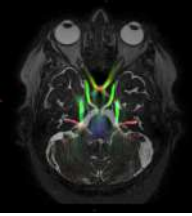
Farquharson et al., 2013

Critères d'arrêt ?

Pipeline



La technique de tractographie implique une **série d'étapes** d'acquisition et de post-traitement



1.a Revue

TABLE 1. Clinical Context: Number of Patients, Pathology, Studied Cranial Nerves, and Visualization Rate

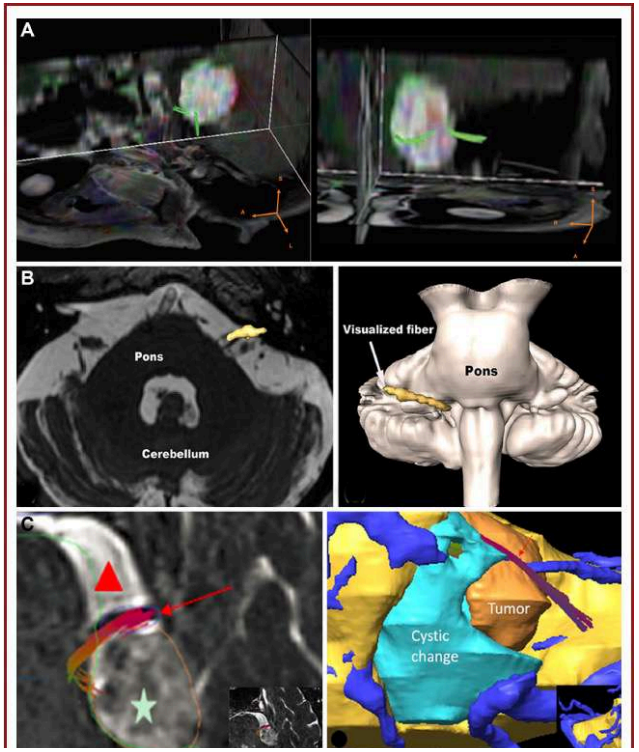
Date	Authors	Patients Participants	Pathology	CN studied	Visualization rate
2006	Taoka et al[20]	8	Vestibular schwannomas	VII/VIII	62.5%
2007	Kabasawa et al[4]	4*	Healthy subjects	V, VIII	100%
2009	Salmela et al[25]	12	Supra sellar tumor	II	100%
2010	Hodaie et al[5]	4*	Healthy subjects	II, III, V, VI, VII/VIII, X	63.6%
2011	Chen et al[22]	3	Vestibular schwannomas	VII/VIII	100%
2011	Fujiwara et al[26]	27	Trigeminal neuralgia	V	100%
2011	Gerganov et al[17]	22	Vestibular schwannomas	VII/VIII	90.9%
2012	Hodaie et al[15]	5	Trigeminal neuralgia	V	100%
2012	Roundy et al[18]	6	Cerebellopontine angle tumors	VII/VIII	100%
2013	Zhang et al[33]	8	Vestibular schwannomas	VII/VIII	87.5%
2014	Choi et al[31]	11	Vestibular schwannomas	VII/VIII	100%
2015	Vos et al[27]	10	Deafness	VIII	100%
2015	Wei et al[23]	23	Vestibular schwannomas	VII/VIII	91.3%
2015	Yoshino et al[12]	22	Vestibular schwannomas	VII/VIII	81.8%
2016	Borkar et al[32]	20	Vestibular schwannomas	VII/VIII	95%
2016	Song et al[19]	15	Vestibular schwannomas	VII/VIII	100%
2016	Hilly et al[21]	28	Cerebellopontine angle tumors	VII/VIII	95,20%
2016	Zhang et al[50]	30	Vestibular schwannomas	VII/VIII	96.7%
2016	Yoshino et al[30]	3 + 4*	« Brain tumors », healthy subjects	All CNs I to XII	100%
2017	Zolal et al[29]	5 + 30*	Skull base tumors, healthy subjects	II, III, V VII/VIII	30-70%
2017	Behan et al[24]	10	Cerebellopontine angle tumors	V, VII/VIII	100%

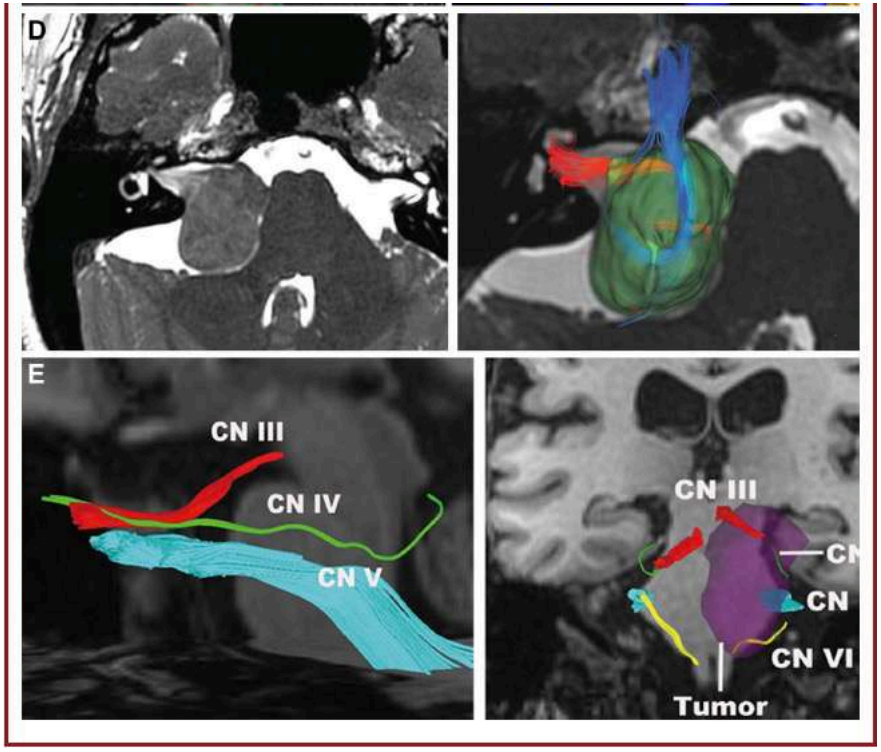
NR = not reported, * = healthy subjects.

21 études de tractographie des nerfs crâniens

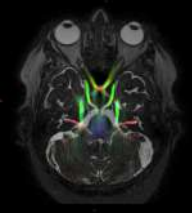
CREATIS

1.a Revue





21 études avec variabilité de paramètres d'acquisition, de post-traitement, et de rendu tridimensionnel



1.a Revue

TABLE 5. Best Set of Acquisition and Tracking Parameters for Routine Practice

Parameters	Value/Comment
MRI acquisition	
Magnetic field (T)	3
Diffusion gradient directions	32 or higher
Diffusion slice thickness (mm)	2 or lower
Diffusion slice gap	0
Diffusion voxel reconstruction	Isotropic
Anatomical reference(s)	High resolution T1 AND T2
Box size	Optic chiasma to foramen magnum
Tracking	
Geometric distortion correction	Eddy & topup FSL® tools
Software	Easy-to-use, "the one you better know"
3D rendering	CNs AND tumor AND anatomical environment
Fractional anisotropy threshold	0.1 or "upper limit"
Curvature threshold	70° or 0.8 rad
Minimal length	5-10 mm
ROI placement	Multiple ROIs, various points of view, according to the CN known anatomical trajectories: brainstem, cistern and foramen

CN: cranial nerve, FSL: FMRIB (Functional Magnetic Resonance Imaging of the Brain) Software library, ROI: region of interest, T: Tesla,

TABLE 6. Practical Guide of ROI Placement for Each Canial Nerve

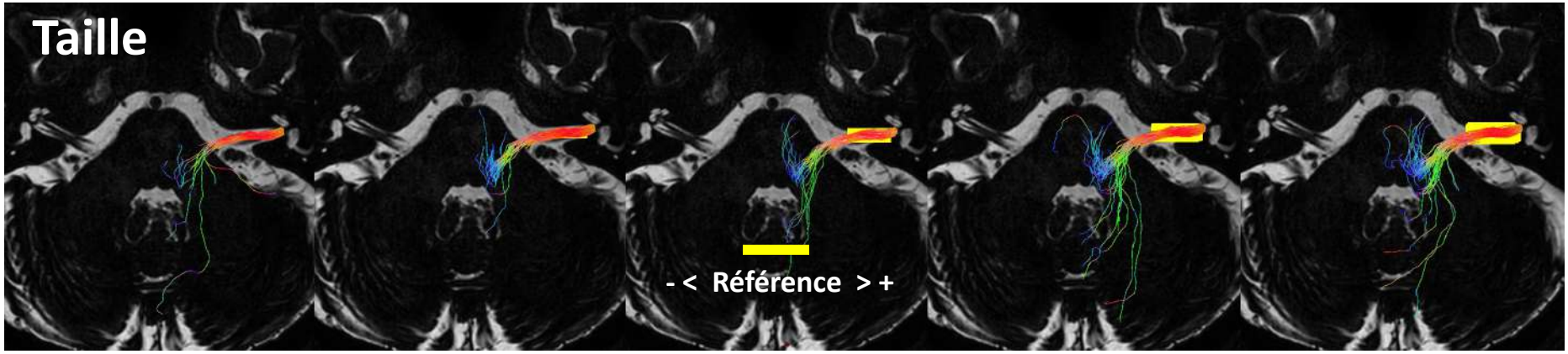
Nerve	ROI placement
Olfactory nerve I	Olfactory groove
Optic nerve II	Intraorbital optic nerve, chiasma+/- LGB
Oculomotor nerve III	Mid-cisternal point
Trochlear nerve IV	Inferior colliculus, cavernous sinus
Trigeminal nerve V	Mid-cisternal point
Abducens nerve VI	Dorello's canal entrance
Facial nerve VII	IAC, facial brainstem nucleus
Vestibulo-cochlear nerve VIII	IAC+/- cochlea
Lower nerves IX, X, XI	Jugular foramen, post-olivary sulcus
Hypoglossal nerve XII	Hypoglossal canal+/-olive

IAC: internal auditory canal, LGB: lateral geniculate body, ROI: region of interest.

Combinaison optimale
des paramètres d'acquisition
et de post-traitement

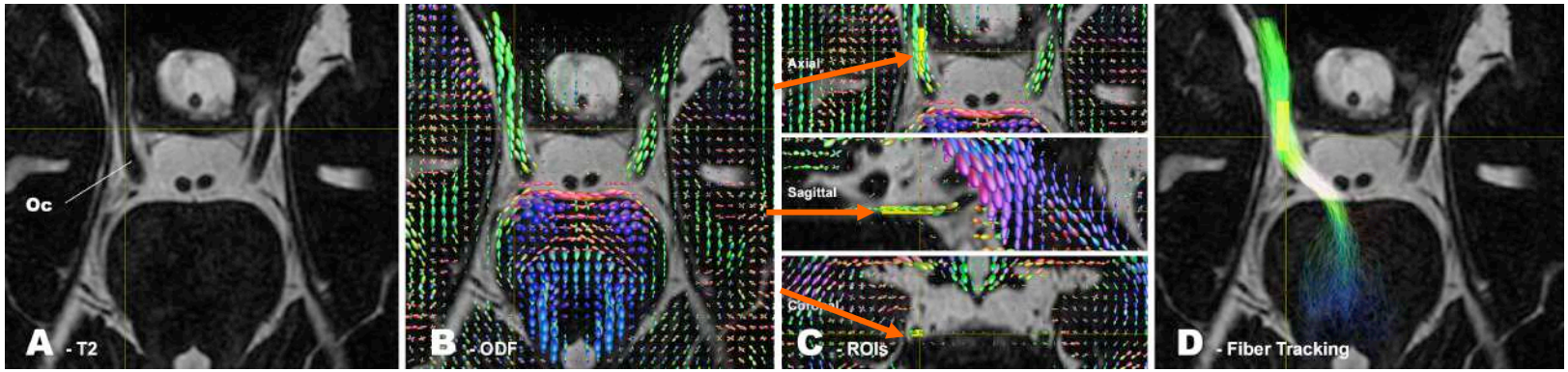
CREATIS

1.a Optimisation



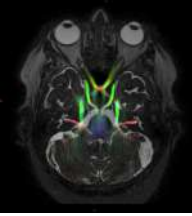
ROI design : influence de la **Taille** et de la **Position**

1.a Optimisation



1. A partir des images anatomiques **T2** (B)
2. Superposition de la carte **ODF** (A)
3. Dessin dans les **3 dimensions** (axiale, sagittale, coronale) (C)
4. Meilleur compromis **ODF-T2** -> trajectoire du nerf crânien
5. **Algorithme** probabiliste avec **critères** optimisés (D)

CREATIS



1.b Série clinique

TABLE 1. Strategy of ROI Placement and Tracking Parameters

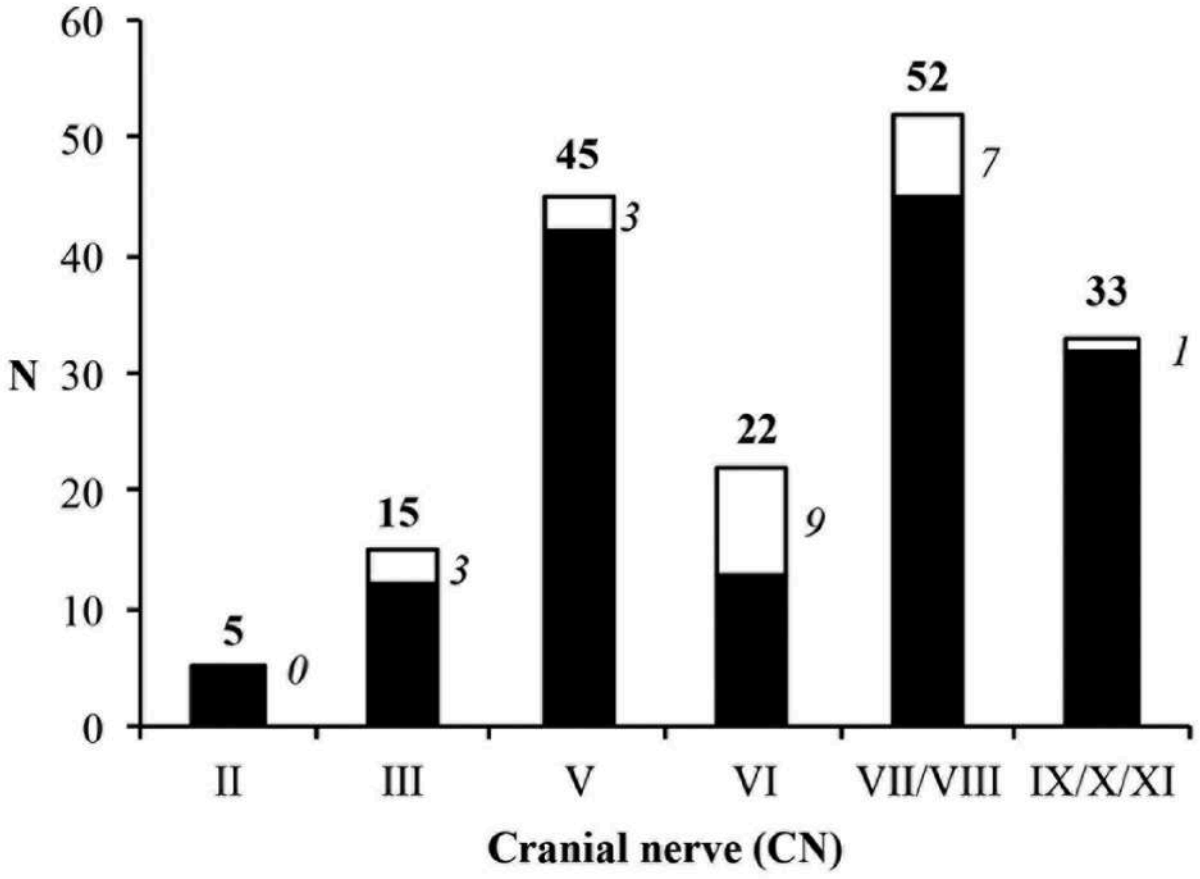
Group	Nerve	ROI placement	Tracking parameters		
			FA threshold	Number of fibers	Other
1	Optic nerve II	Whole optic chiasma	0.3	1000	Maximal curvature angle = 45°
2	Oculomotor nerve III	Cisternal segment before cavernous sinus	0.3	500	
3	Trigeminal nerve V	Mid-cisternal point	0.3	700	
4	Abducens nerve VI	Dorello canal entrance	0.2	100	
5	Acoutic facial bundle VII-VIII	Whole Internal Acoustic Canal	0.3	300	Minimal length = 10mm
6	Lower nerves IX, X, XI	Cisternal segment at the flocculus level	0.2	200	

FA: fractional anisotropy.
ROI: region of interest.

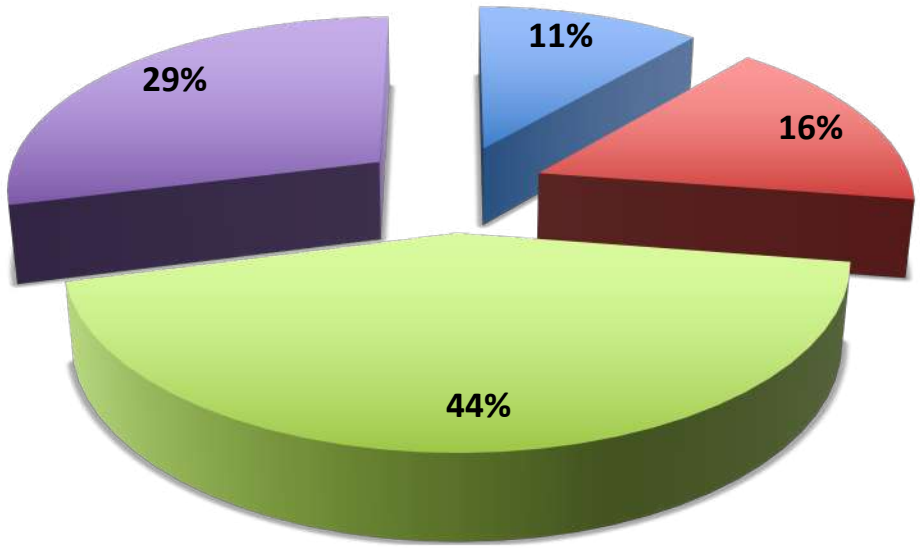
- IRB Number 2015-A01113-46, Clinical.gov
- Etude monocentrique 2015-2017 ouverte
- **62** patients, tumeurs complexe de la base du crâne
- **6** groupes de nerfs crâniens : II, III, V, VI, NF (VII-VIII), LN (IX/X/XI)
- Nerf Trochléaire trop fin
- Nerfs olfactif and hypoglosse “hors acquisition IRM”

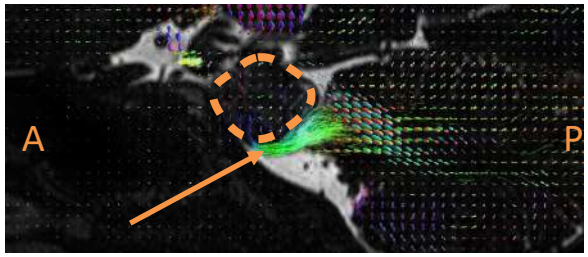
CREATIS

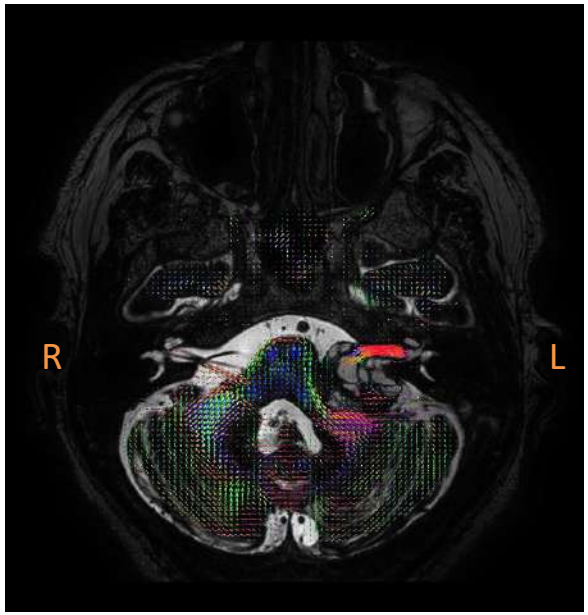
1.b Série clinique



1.b Série Clinique







Ajustement de la **stratégie chirurgicale** dans **44** (71%) cas :
décision chirurgie, choix voie d'abord, résection

1.b Échecs

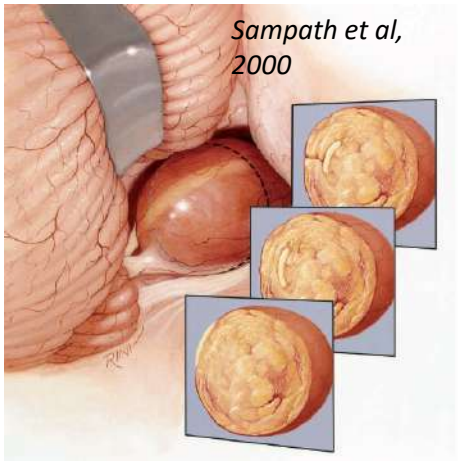
23 échecs de tractographie
9 discordances tractographie-chirurgie

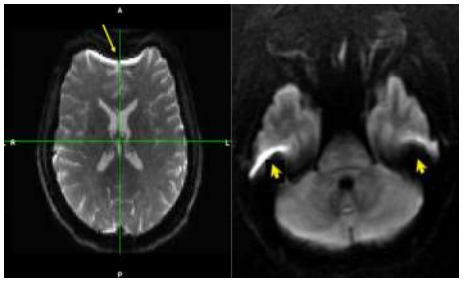
Difficultés de la technique liées à :

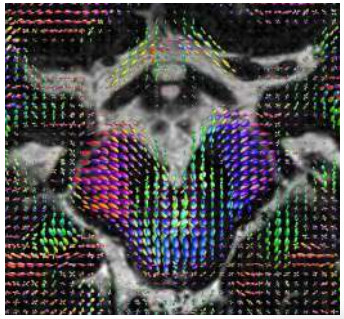
1. **Tumeur** : kystique, volume, remplissage du MAI, signal de diffusion tumeur = nerf (schwannomes)

2. **Nerf crânien :** écartèlement en “papier bonbon” englobement intra-tumoral, fusion avec capsule, déplacement +++, placement des ROIs

3. **Environnement anatomique :**
confusion artères / veines,
remaniements tumoraux +++,
recrutement des fibres du tronc cérébral *(fiber crossing),*
artefacts et distorsions à la base du crâne,
fausses continuations



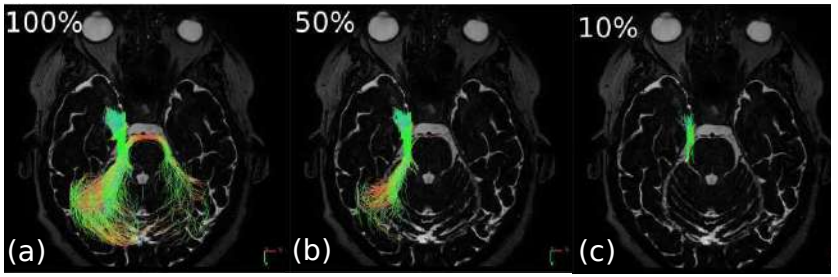




1.b Filtrage

Entropie = mesure du désordre

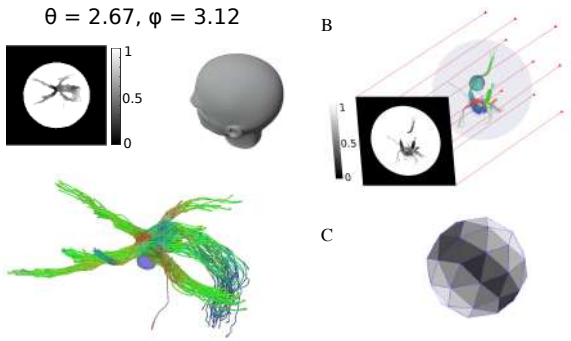
À partir de l'IRM de diffusion
Création d'une carte d'entropie

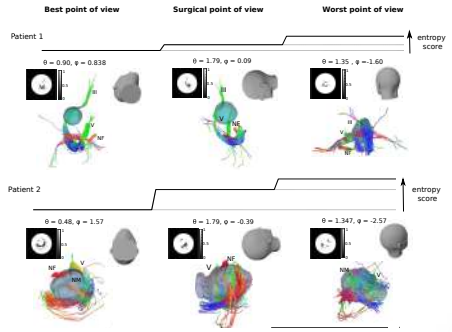


1. Elimination des fibres à entropie élevée
   = Filtrage

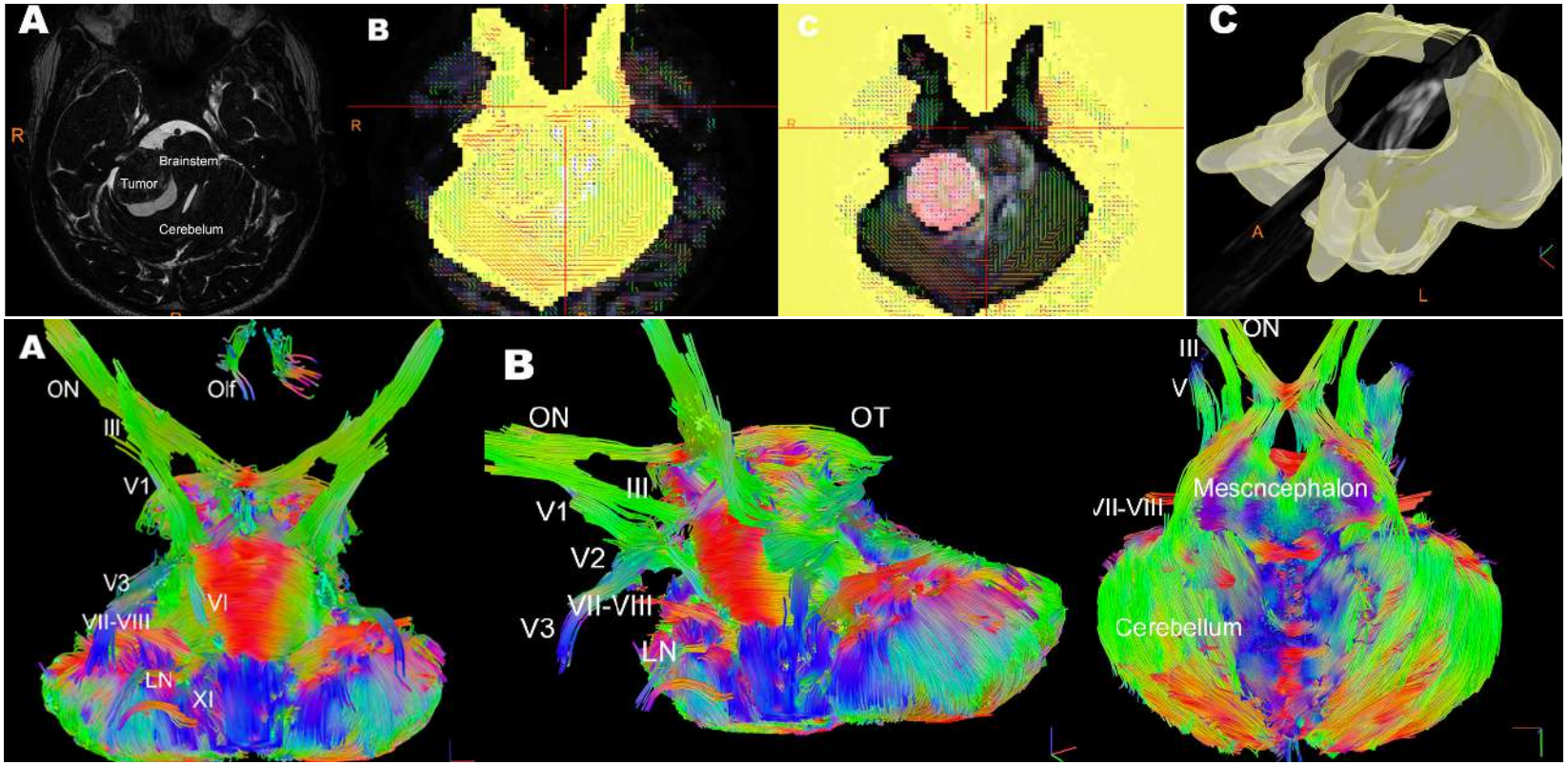
1. Sélection d'un point de vue optimal
   comparaison de 60 PdV
   PdV meilleur/pire/chirurgical

   N=28
   PdV meilleur > chir > pire
   automatisation PdV > si taille tumeur ↑





1.c *Full brainstem tractography*

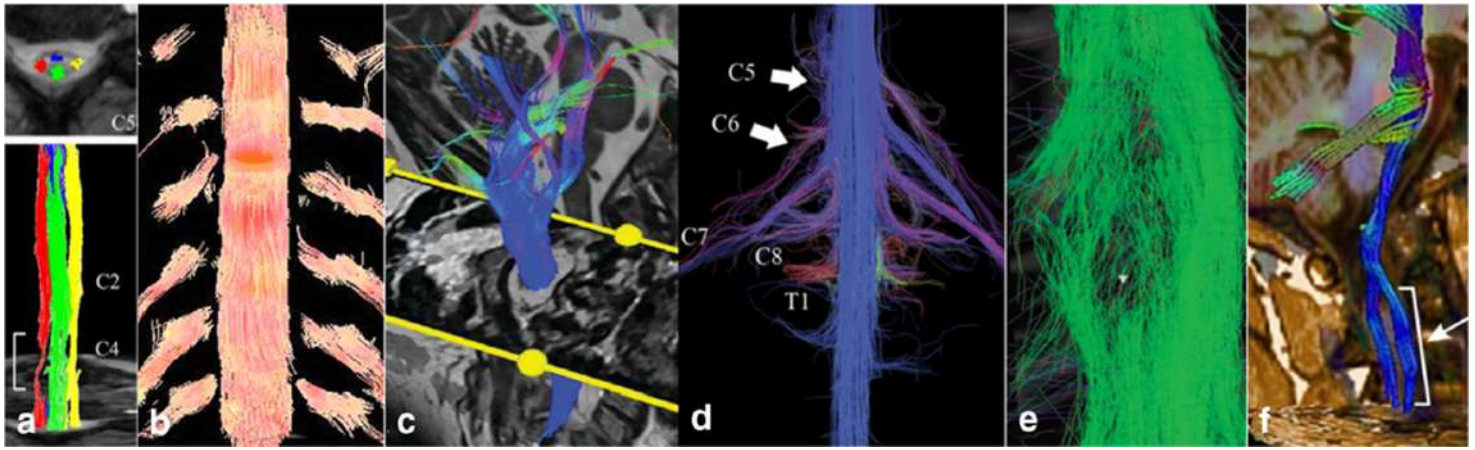


Jacquesson et al., JNS, 2019

1 région d'exclusion et reconstruction du volume complet
50 000 fibres, default FA, angle <60° , longueur min 10mm

1.c *Full brainstem tractography*

2.a Spinal cord tractography



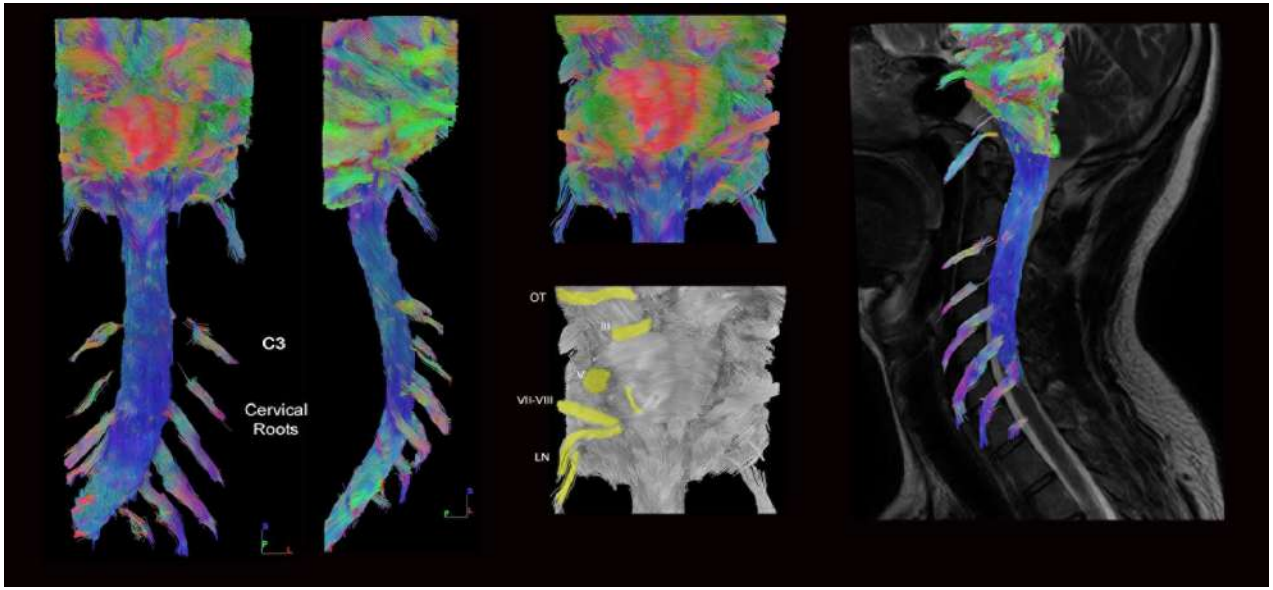
Parameters	Value/comment
MRI acquisition	
Magnetic field (T)	1.5 or 3
Diffusion gradient directions	20 or higher
b value	Between 700 and 1000 s mm^{-2}
Diffusion slice thickness (mm)	2 or lower
Diffusion slice gap	0
Diffusion voxel reconstruction	Isotropic
Field of view	Reduced
TR/TE	Synchronized with the heartbeat for the thoracic cord/ lower as possible
Acquisition plane	Axial
Phase-encoding direction	Right-left: cervical spinal cord
	Antero-posterior: thoracic spinal cord
Anatomical reference	T2-weighted imaging
Tracking	
Software	With determinist approach
Fractional anisotropy threshold	Between 0.15 and 0.2
Curvature threshold	40°
ROI placement	Avoiding CSF and GM

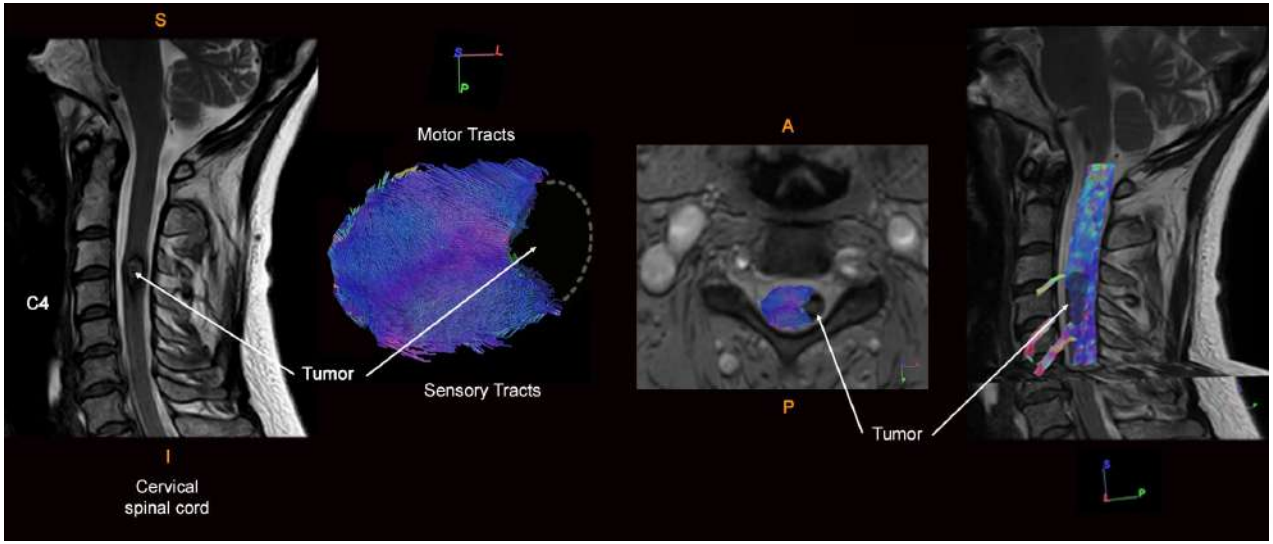
41 études de tractographie de la moelle spinale

Combinaison optimale
des paramètres d'acquisition
et de post-traitement

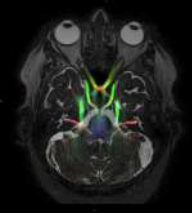
CREATIS

2.b *Full cervical cord tractography*





CREATIS



2.b *Full cervical cord tractography*

CREATIS

3.a Key points

SURGICAL ANATOMY AND TECHNIQUE

Emile Simon, MD, MSc*
Pierre-Aurélien Beuriat, MD, PhD*
Violaine Delabar, MD‡
Emmanuel Jouanneau, MD, PhD‡
Juan Fernandez-Miranda, MD§
Timothée Jacquesson, MD, PhD*‡||

Cranial and Cerebral Anatomic Key Points for Neurosurgery: A New Educational Insight

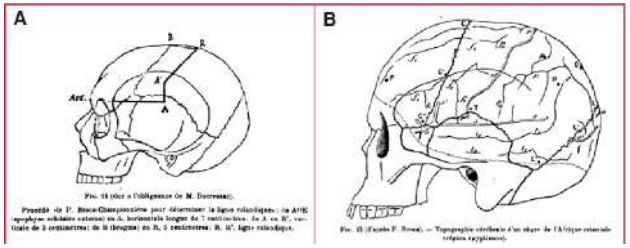


TABLE 1. Summary of All 16 Cranial and Cerebral Key Points and Their Location

	Cranial key point	Abbreviation	Location	Cerebral correlation
1	Anterior coronal point	ACoP	10 mm anterior to the coronal suture and 30 mm lateral	Kocher's point
2	Anterior squamous point	ASqP	Squamous-sphenoparietal suture meeting point	Limen insulae//ASyP
3	Asterion	As	Lambdoid-parietomastoid suture meeting point	Transverse-sigmoid junction of lateral sinus
4	Bregma	Br	Coronal-sagittal suture meeting point//120-140 mm posterior to the nasion	Interventricular foramen
5	Euryon	Eu	Parietal bossa	Superior aspect of supramarginal gyrus
6	Inion	In	External occipital protuberance	Torcula//lateral sinus meeting point
7	Intraparietal point	IPP	50 mm anterior to the Lambda lateral to the sagittal suture	IPS-PostCS meeting point
8	Lambda	La	Lambdoid-sagittal suture meeting point//120-140 mm posterior to the bregma	Parieto-occipital fissure//junction between cuneus and precuneus
9	Nasion	Na	Frontonasal suture	Anterior skull base
10	Opisthocranion	Op	Occipital bossa//20-40 mm above the inion	Calcarine sulcus
11	Posterior coronal point	PCoP	10 mm posterior to the coronal suture and 30 mm lateral	SFS-PreCS meeting point
12	Preauricular point	PreAP	Bone depression anterior to the EAM	Half of the petrous pyramid//middle cranial base level
13	Stephanion	St	Coronal suture-linea temporalis meeting point	IFS-PreCS meeting point
14	Superior sagittal point	SSaP	50 mm posterior to the Bregma	PreCS//SRP
15	Superior squamous point	SSqP	Superior aspect of squamous suture//25 mm posterior to the ASqP	PreCS//IRP
16	Temporoparietal point	TTP	30 mm superior to the parietomastoid suture	Posterior end of STG//atrium of the lateral ventricle

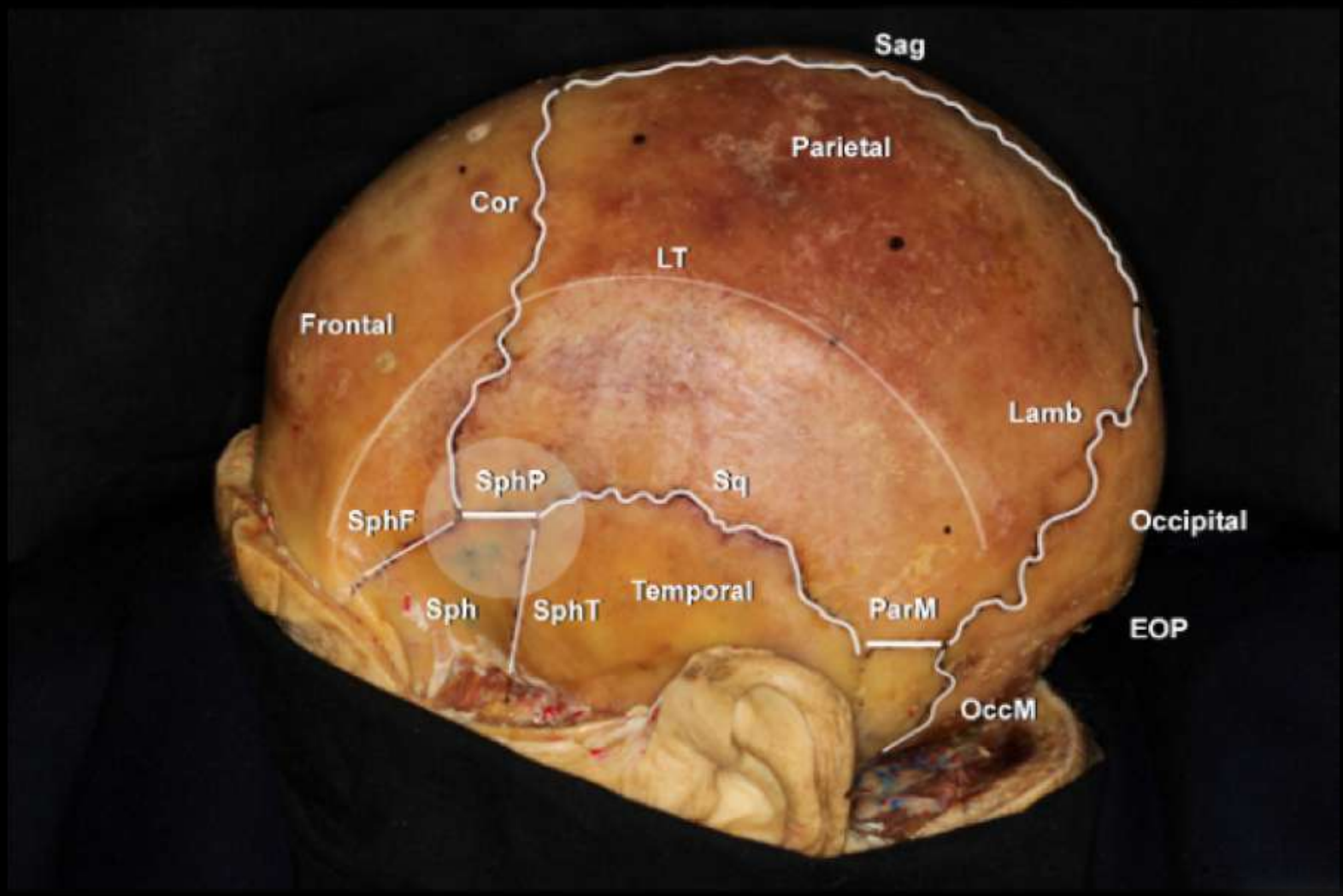
ASyP, anterior sylvian point; EAM, external acoustic meatus; IFS-PreCS, inferior frontal sulcus-precentral sulcus; IRP, inferior rolandic point; SFS-PreCS, superior frontal sulcus-precentral sulcus; SRP, superior rolandic point; STG, superior temporal gyrus.

Jacquesson et al., ONS, 2022

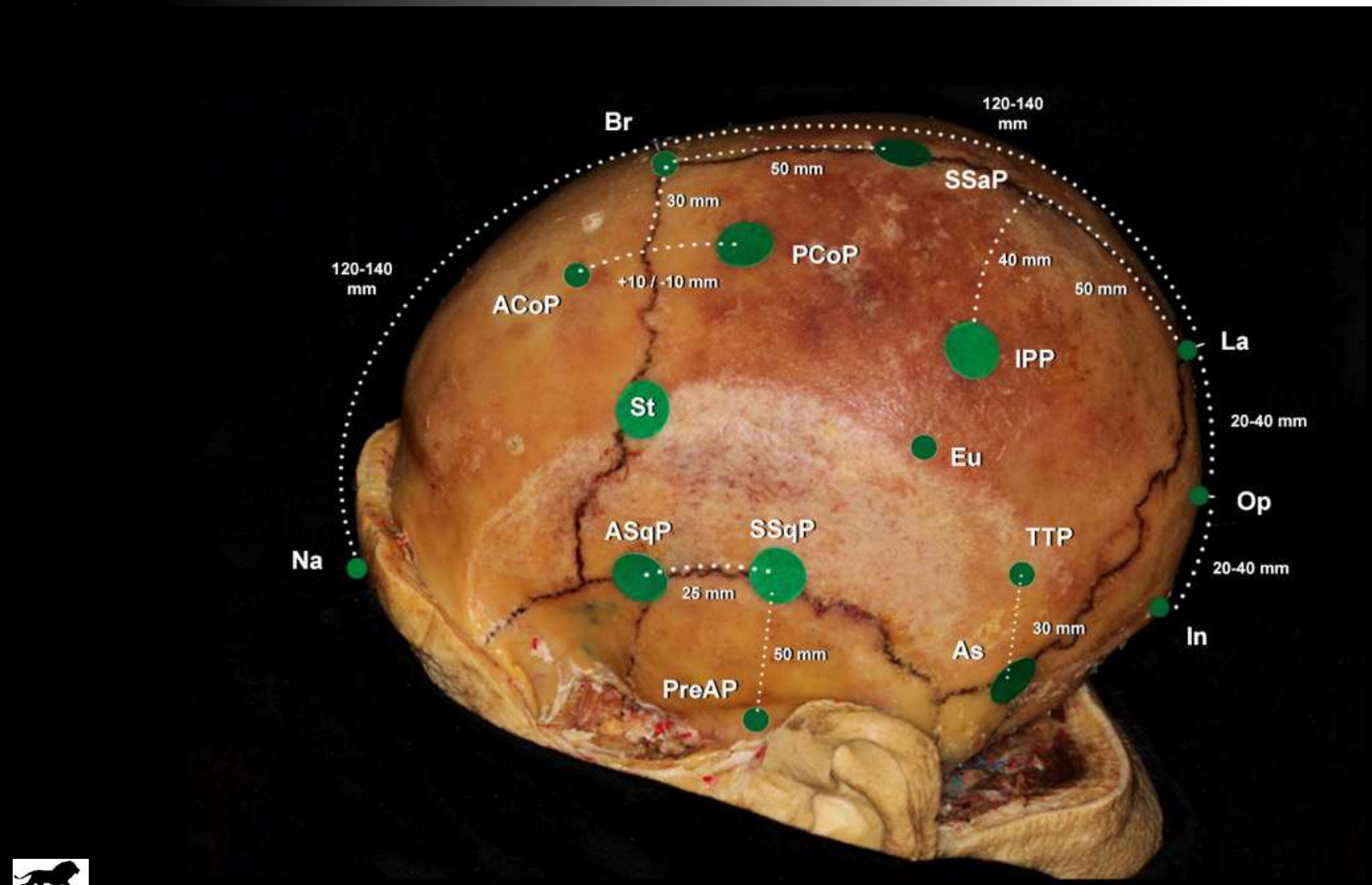
CREATIS

3.a *Key points*

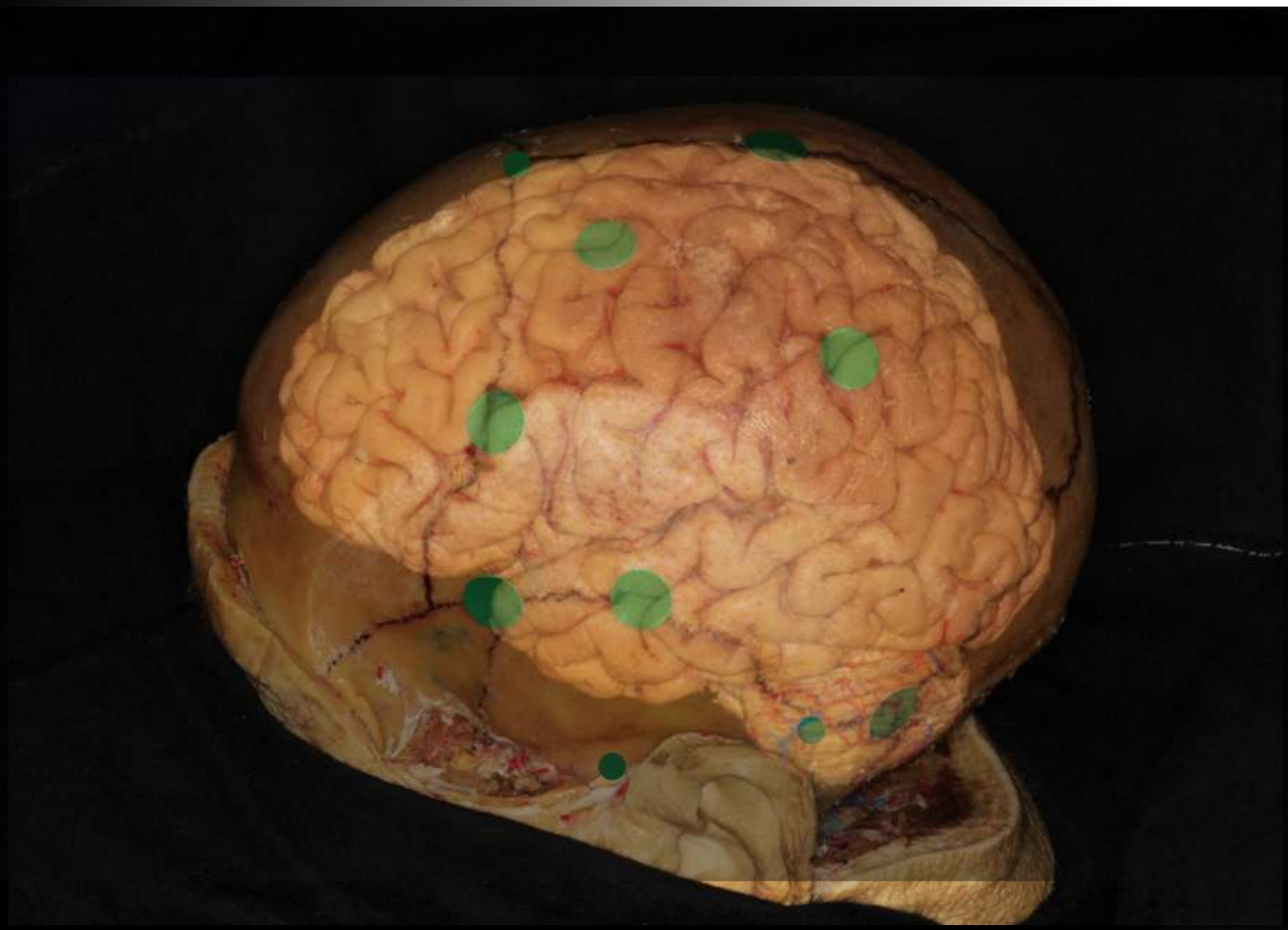
3.a *Key points*

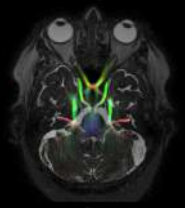


3.a *Key points*

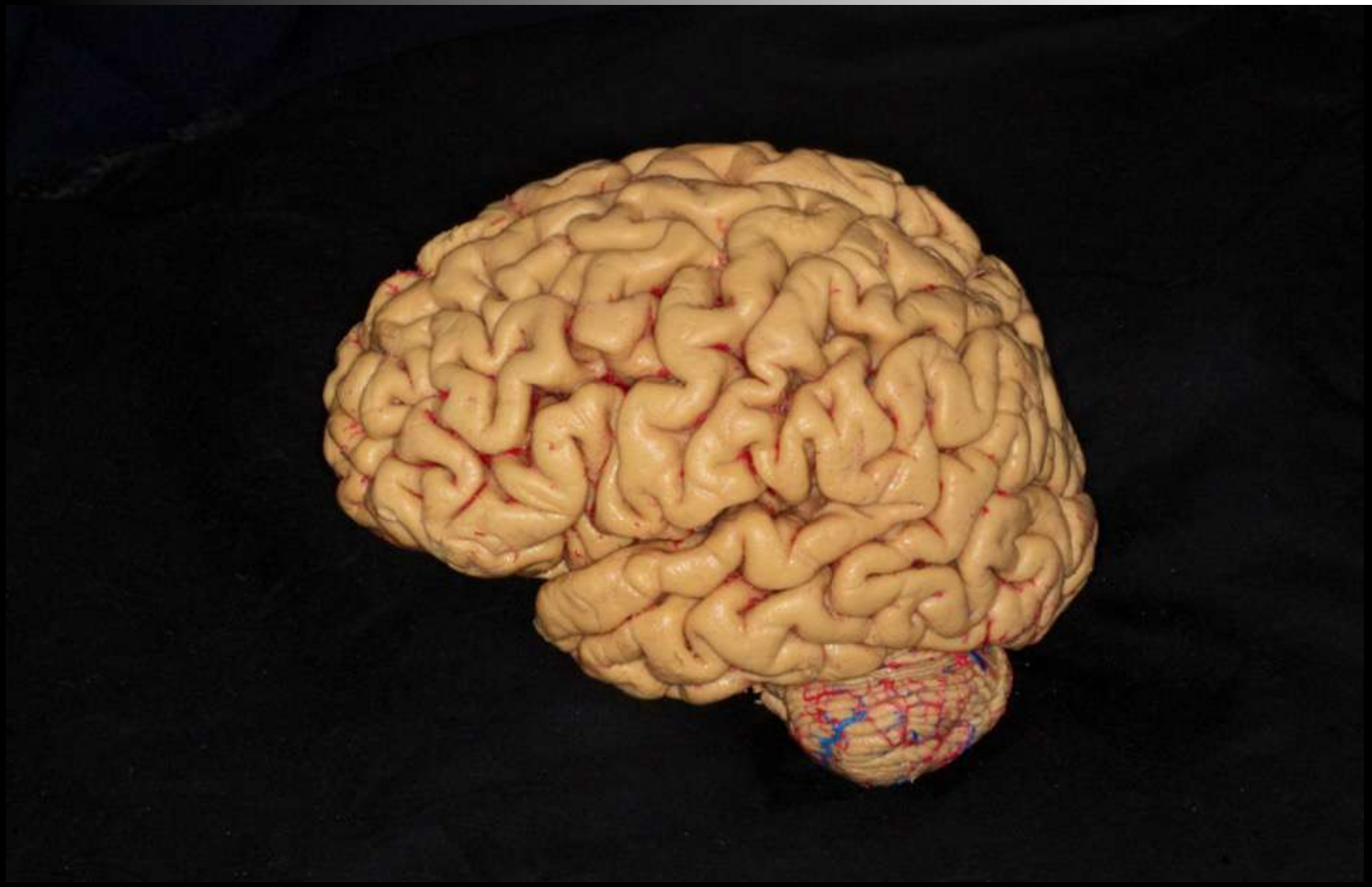


3.a *Key points*

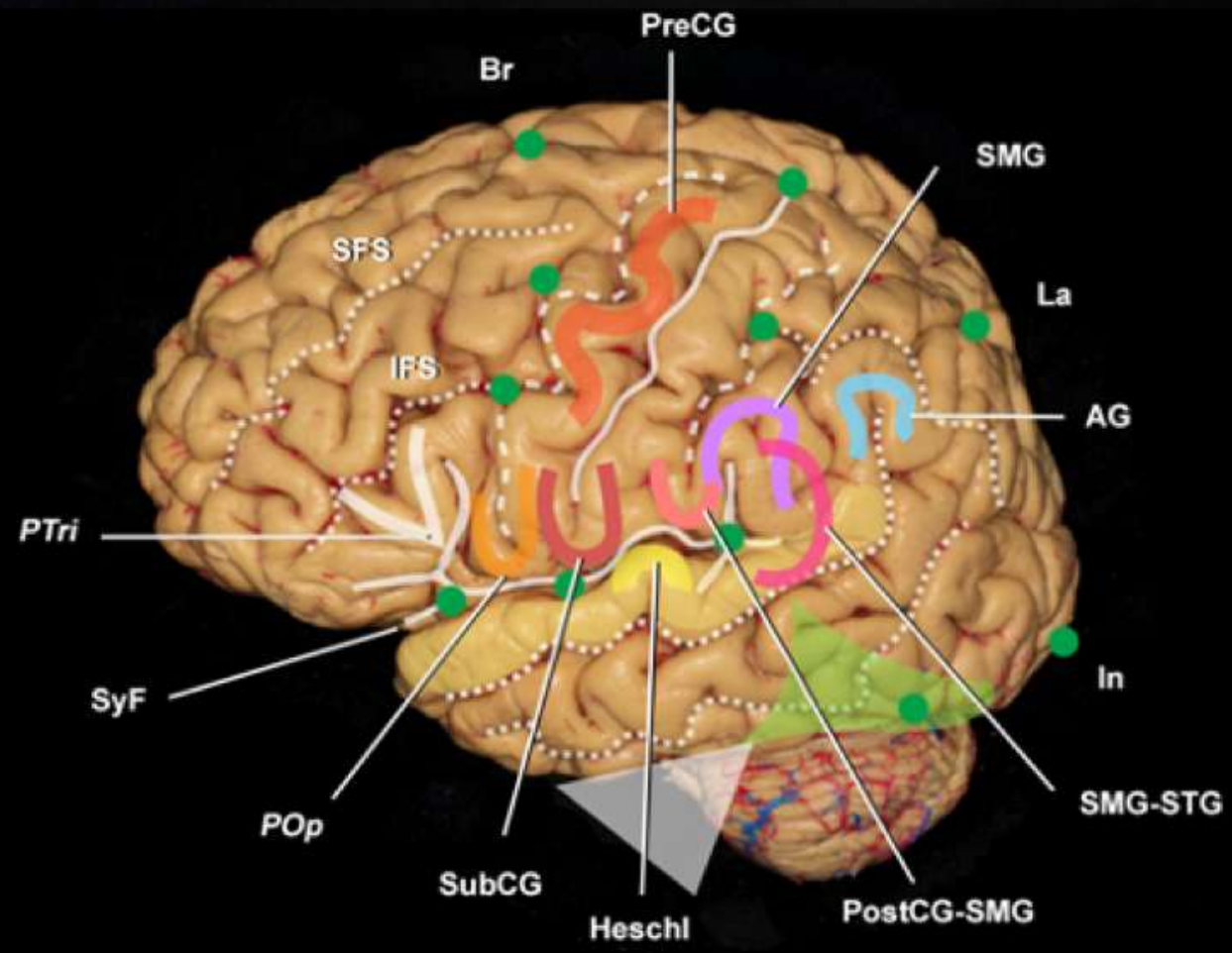




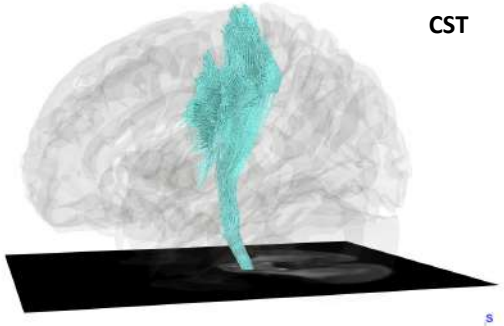
3.a *Key points*

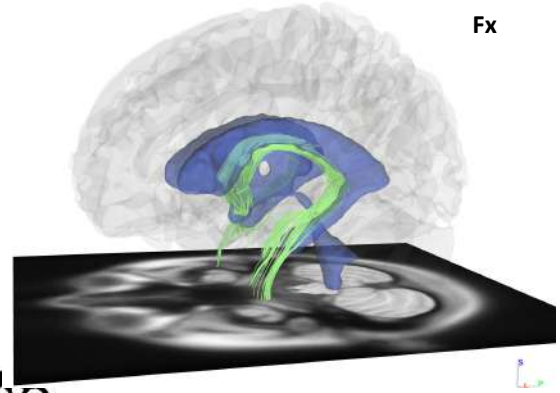


3.a *Key points*



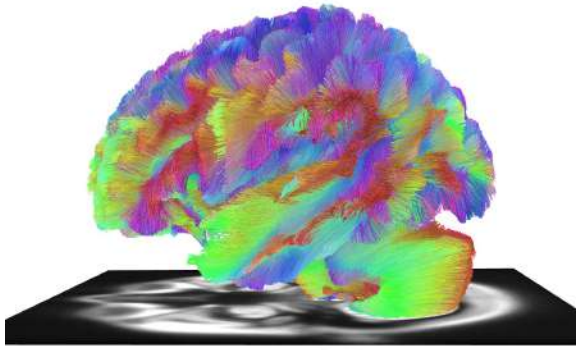
3.b White Matter 3D

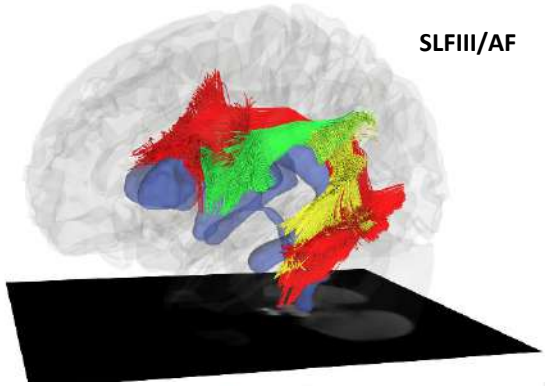




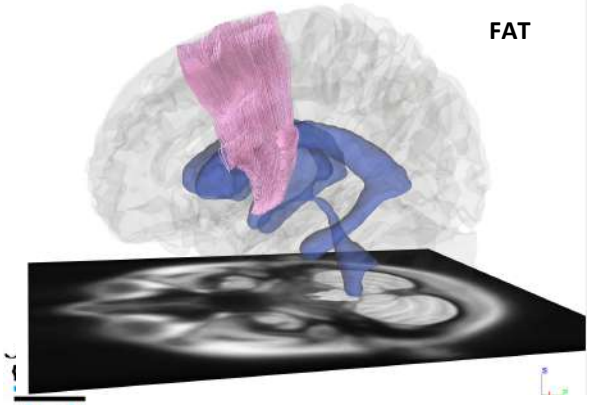
Num	Abbr.	Name	Endpoints	Function	Damage	Operative Test	
Projection							
1	FPT	Fronto pontine tract	Supplementary Motor Areas – Pons	Complex motor command	Movements disorders	Complex motor task	
2	CST	Cortico-spinal tract	Precentral gyrus – Spinal cord	Motor signal brain to body + limbs	Motor deficit	Motor task (“dystonic” or “positive” motor mapping)	
3	TPOPT	Temporo-Parieto-occipito-pontine tract	Temporal pole, + superior parietal gyrus + occipital pole – Pons	Sensitivity integration	Unknown	N/A	
4	TCT	Thalamo-cortical tract	Thalamus - Primary somatosensory cortex	Somatosensory inputs	Dysesthesia	Patient’s subjective complaints	
5	FST	Fronto-striatal tract	Supplementary motor area – Caudate nucleus	Movement initiation, movement coordination	Motor arrest	Movements tasks / bimanual tasks (negative motor mapping)	
Connection / Commisural							
6	CC	Corpus callosum	Occipital, frontal and parietal lobes – Contralateral hemisphere	Bilateral coordination	Motor coordination loss	N/A	
7	AC	Anterior commissure	Temporal and occipital regions on both sides	Visual process, memory, behavior	memory and behavioral disorders	N/A	

3.b White Matter 3D





SLFIII/AF

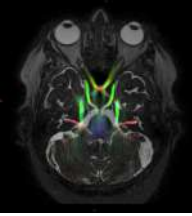


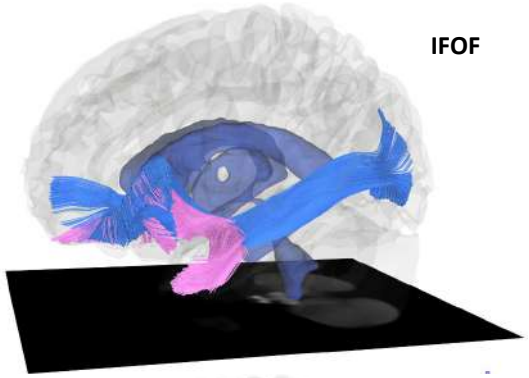
FAT

Num	Abbr.	Name	Endpoints	Function	Damage	Operative Test	
Association							
Dorsal stream							
8	SLF I	Superior longitudinal fasciculus I	Medial part of Superior frontal gyrus – Medial part of Superior parietal gyrus	Initiation of movements, Complex movements, Attention	Spatial neglect (eye movements disorders)	N/A	
9	SLF II	Superior longitudinal fasciculus II	Middle frontal gyrus – inferior parietal gyrus	Attention, focusing, visuospatial awareness	Spatial Neglect Attention disorders	Line bisection task Dual-tasking	
10	SLF III /AF horizontal	Superior longitudinal fasciculus III - horizontal	Inferior frontal gyrus (VPMC) – inferior parietal gyrus	Articulatory aspect of the language (left) Visuospatial cognition and attention (right)	Dysarthria Attention disorders	Naming tasks (DO80) Dual-tasking	
	SLF III /AF vertical	Superior longitudinal fasciculus III - vertical	Inferior parietal gyrus – middle temporal gyrus				
	SLF III /AF inner "AF"	Arcuate fasciculus	Inferior frontal (Broca's area), middle frontal (DLPFC), and precentral gyrus - Superior temporal (Wernicke's area), middle and Inferior temporal gyrus (basal temporal areas and visual word form area VWFA)	Phonological aspects of the language	Phonemic paraphasia, prosodic troubles, jargonaphasia	Naming tasks (DO80) Reading aloud tasks (regular, irregular and pseudo-words, ECLA16+)	
11	FAT	Frontal aslant tract	Pars opercularis & triangularis – Superior frontal gyrus	Speech initiation	Stuttering	Fluency tasks, Counting, Naming tasks (DO80)	

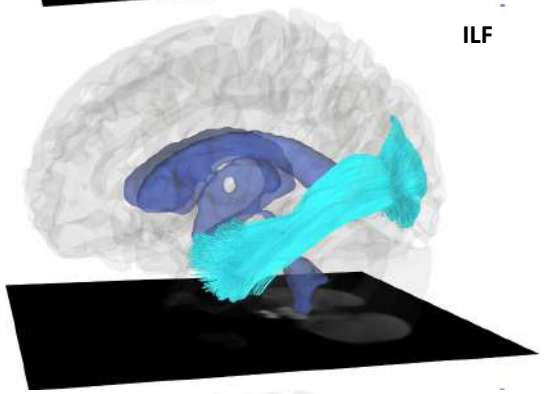
CREATIS

3.b White Matter 3D

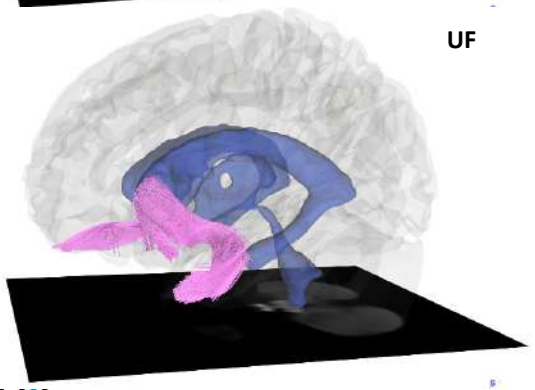




IFOF



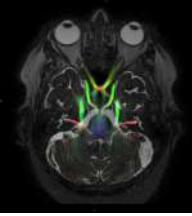
ILF



UF

Num	Abbr.	Name	Endpoints	Function	Damage	Operative Test
Ventral stream						
12	IFOF	Inferior Fronto Occipital fasciculus	Occipital lobe – Frontal lobe (Orbitofrontal cortex and DLPFC)	Verbal and non-verbal semantic processing (left),. Face-based mentalizing (right)	Semantic paraphasia (left) and disorders at semantic image association tasks (left and right); Face-based mentalizing disorders (mostly right), self-confidence disorders	Semantic association tasks (Palm and Pyramid Tree test, PPTT) Read the mind in the Eyes task (RME) Self-confidence Index (SCI)
13	ILF	Inferior longitudinal fasciculus	Dorsolateral Occipital lobe – Temporal pole	Lexical retrieval (anterior part) Reading, object identification, , , visual memory (posterior part)	Anomia, Pure alexia, lexical-semantic alexia, Visual agnosia	Naming tasks (DO80) (anterior part) Reading aloud tasks (regular, irregular and pseudo-words, ECLA16+, posterior part)
14	MdLF	Middle longitudinal fasciculus	Temporal pole – Angular gyrus + Upper occipital lobe	Sound location, sound memory (right), spatial perception (left)	Sound memory and space orientation loss, vertigo and confusion	N/A
Medial / Limbic stream						
15	UF	Uncincate fasciculus	Orbitofrontal areas – Temporal pole	Behavior, emotion, and working memory proper name retrieval	Behavioral disorders, memory & emotional disorders, proper name aphasia	Naming task (DO80), Eckman's faces
16	Cing	Cingulum	Orbitofrontal cortex – Parahippocampal gyrus	High-level integrated cognitive functions	Disruption of consciousness and awareness of external environment. "Dream-like" sensation, Attentional/executive functions deficit	Self-confidence Index (SCI), Dual-tasks
17	Fx	Fornix	Mammillary bodies – Hippocampus + Amygdala)	Memory process	Impairment of recall memory	Memory test

CREATIS



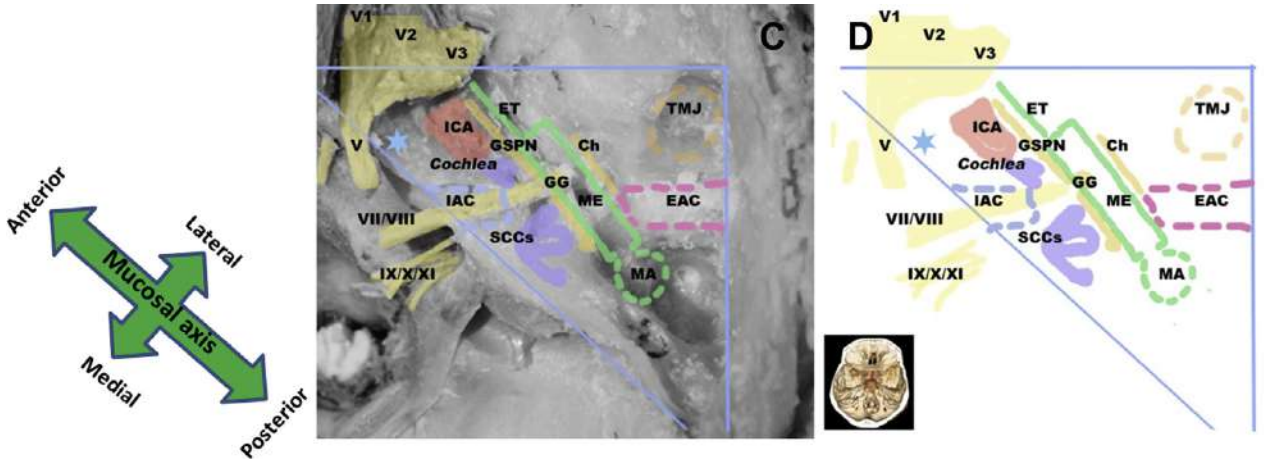
3.b *White Matter 3D*

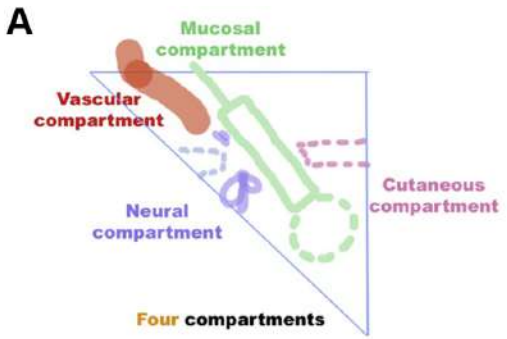
CREATIS

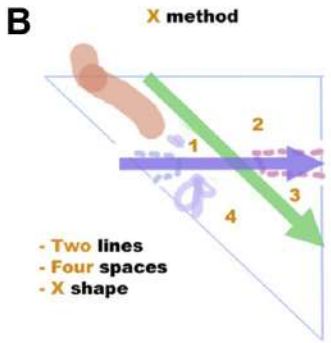
3.c *Petrous Bone segmentation*

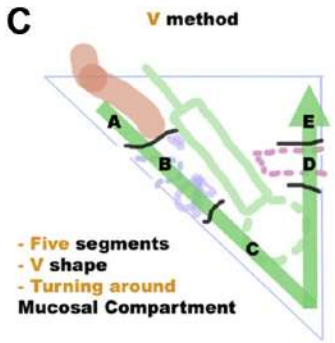
Understanding Anatomy of the Petrous Pyramid—A New Compartmental Approach

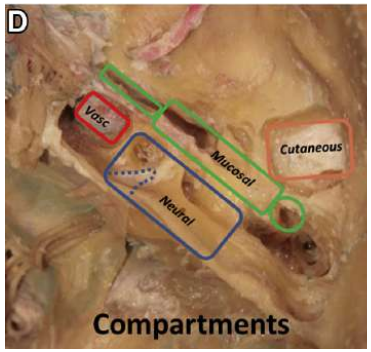
Mamdouh Tawfik-Helika[1], Patrick Mertens[2], Guilherme Ribas[3], Michael D. Cusimano[4], Martin Catala[5], Ramez Kirollos[6], Timothée Jacquesson[2,7]

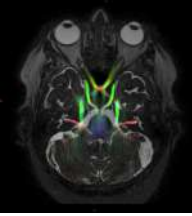












3.c Vertebral artery loop

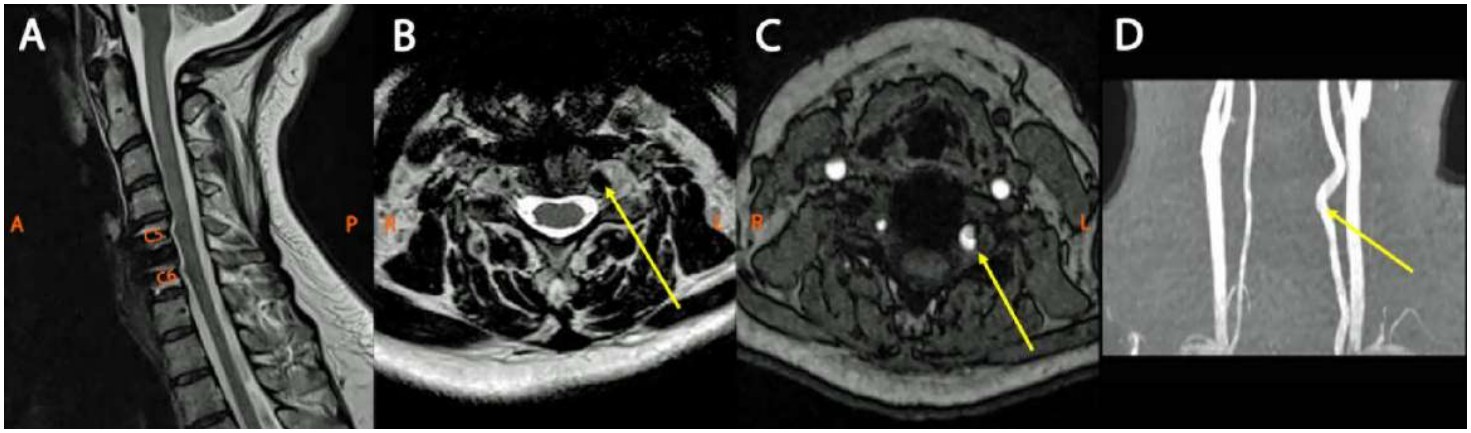
Surgical and Radiologic Anatomy
https://doi.org/10.1007/s00276-022-02885-z

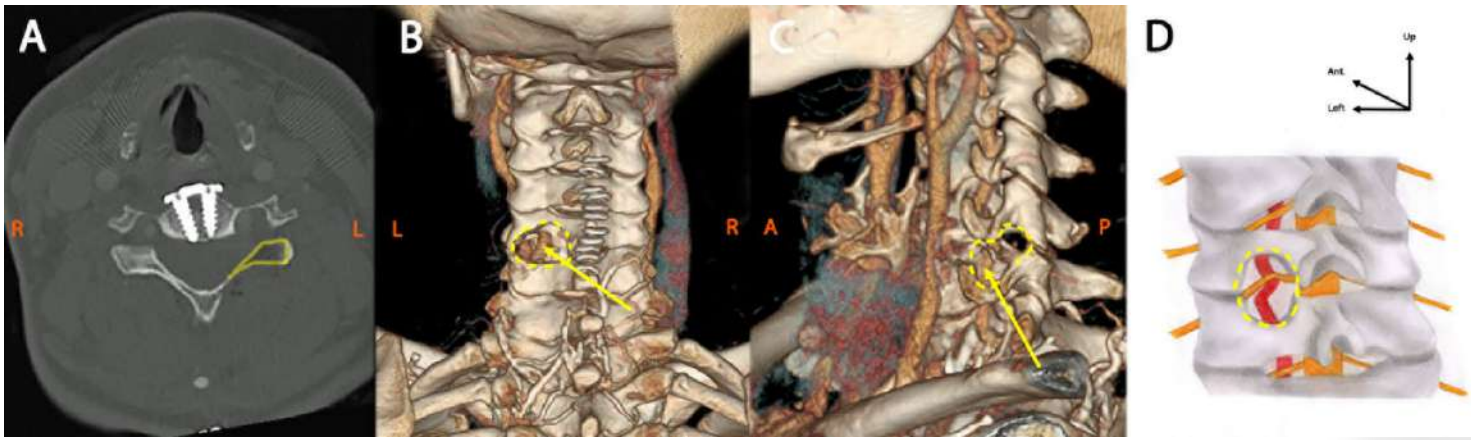
ANATOMIC VARIATIONS

Cervicobrachial neuralgia due to vertebral artery loop

Marine Rigal[1] · Sylvain Portet[2] · Emmanuel Jouanneau[1,2] · Roberto Riva[3] · Omer Eker[3] · Timothée Jacquesson[1,4]

Received: 6 September 2021 / Accepted: 8 January 2022





CREATIS

3.d Photographie 360

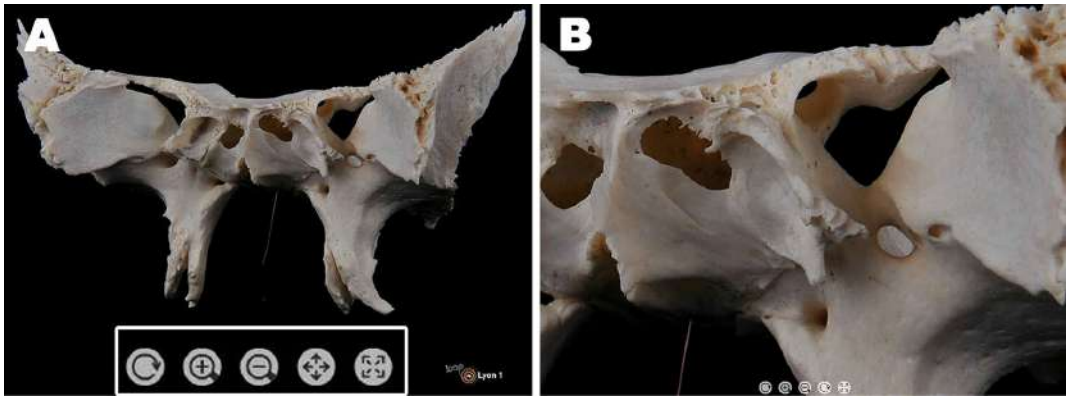
Surg Radiol Anat
DOI 10.1007/s00276-016-1702-1

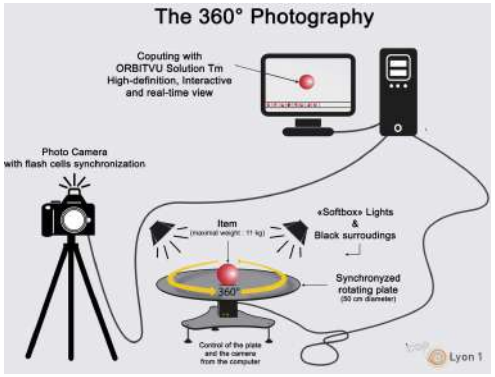
CrossMark

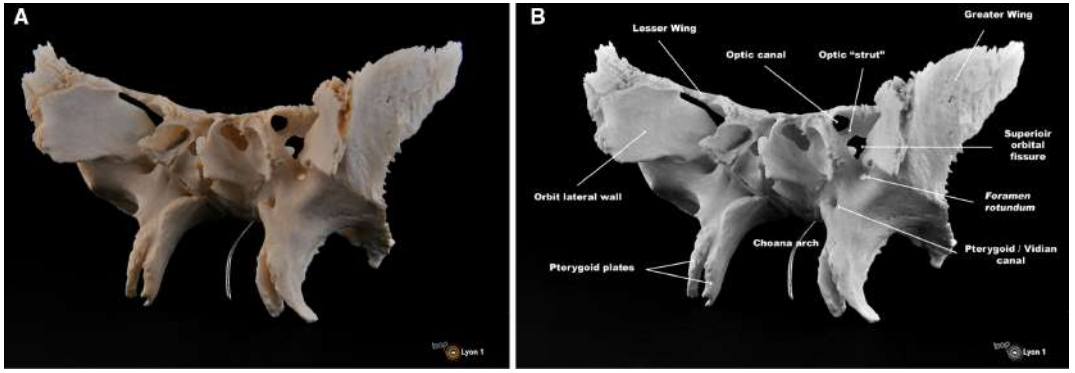
TEACHING ANATOMY

The 360 photography: a new anatomical insight of the sphenoid bone. Interest for anatomy teaching and skull base surgery

Timothée Jacquesson[1,2,3] · Patrick Mertens[2] · Moncef Berhouma[1] · Emmanuel Jouanneau[1] · Emile Simon[2]







3.d Photographie 360

3.d Photogrammetrie

Surg Radiol Anat
DOI 10.1007/s00276-016-1702-1

TEACHING ANATOMY

The 360 photography: a new anatomical insight of the sphenoid bone. Interest for anatomy teaching and skull base surgery

Timothée Jacquesson[1,2,3] · Patrick Mertens[2] · Moncef Berhouma[1] · Emmanuel Jouanneau[1] · Emile Simon[2]

Département Universitaire d'Anatomie Rockefeller - LYON - FRANCE
Dr. Timothée **JACQUESSON** - Dr. Emile **SIMON** - Pr. Patrick **MERTENS**

Crédit photos : Nadine BEYSSERIAT - Service iCAP - Université Claude Bernard Lyon 1

Lyon 1 UNR-RA AUVERGNE – RhôneAlpes

CREATIS

3.d Stéréoscopie

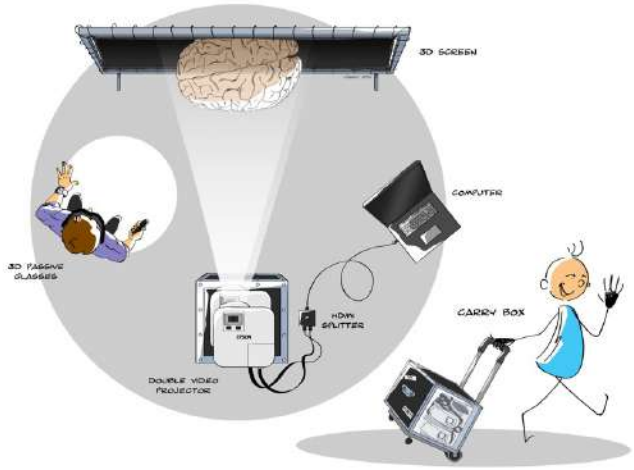
Surgical and Radiologic Anatomy (2020) 42:719–727
https://doi.org/10.1007/s00276-020-02442-6

TEACHING ANATOMY

Stereoscopic three-dimensional visualization: interest for neuroanatomy teaching in medical school

Timothée Jacquesson[1,2] · Emile Simon[1,4] · Corentin Dauleac[1] · Loïc Margueron[1] · Philip Robinson[3] · Patrick Mertens[1,4]

Received: 30 January 2020 / Accepted: 10 February 2020 / Published online: 29 February 2020



3.d Stéréoscopie

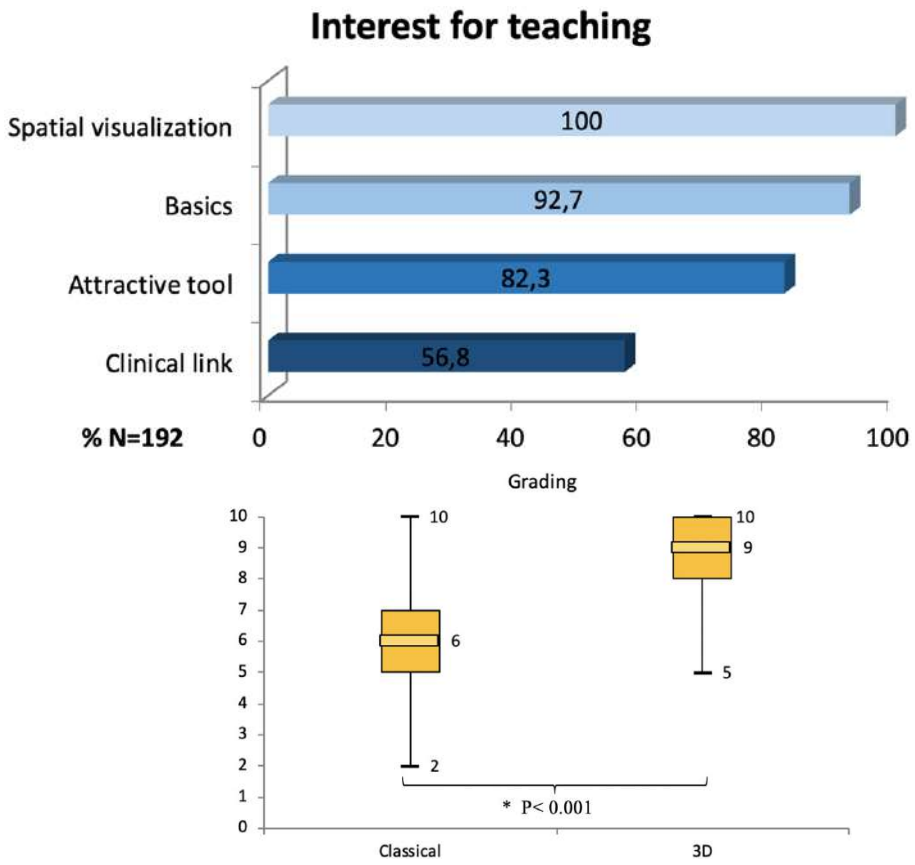
Surgical and Radiologic Anatomy (2020) 42:719–727
https://doi.org/10.1007/s00276-020-02442-6

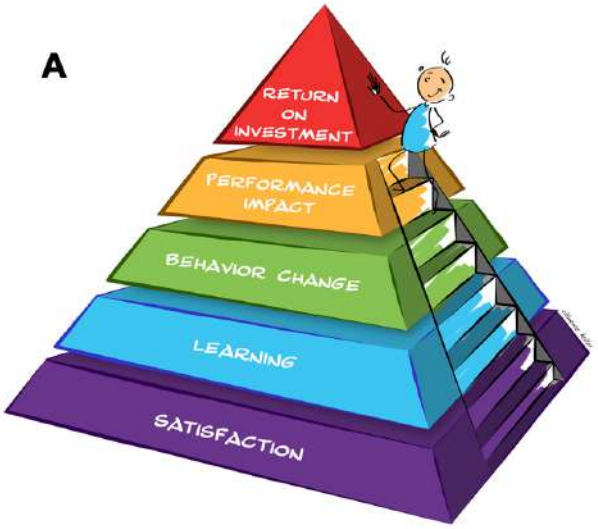
TEACHING ANATOMY

Stereoscopic three-dimensional visualization: interest for neuroanatomy teaching in medical school

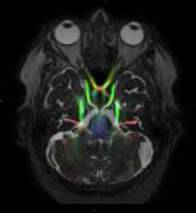
Timothée Jacquesson[1,2] · Emile Simon[1,4] · Corentin Dauleac[1] · Loïc Margueron[1] · Philip Robinson[3] · Patrick Mertens[1,4]

Received: 30 January 2020 / Accepted: 10 February 2020 / Published online: 29 February 2020





- Yes
- Rather Yes
- Rather No
- No



3.d Stéréoscopie

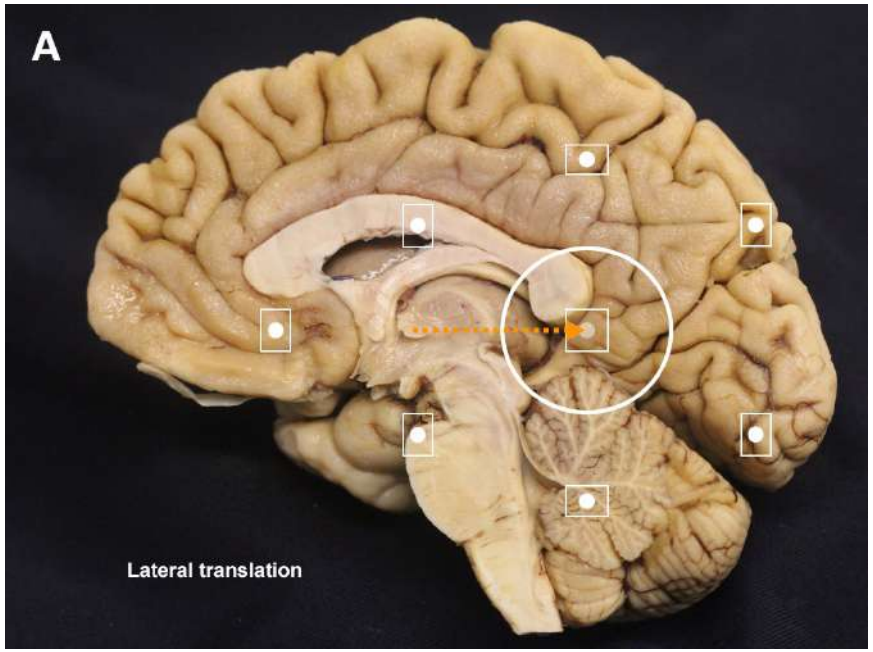
Surgical and Radiologic Anatomy (2020) 42:719–727
https://doi.org/10.1007/s00276-020-02442-6

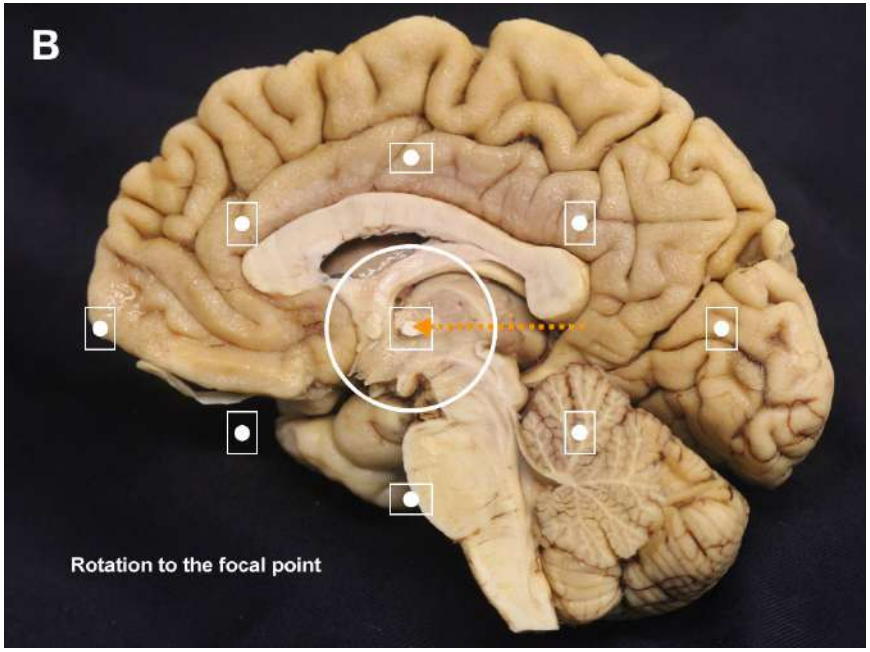
TEACHING ANATOMY

Stereoscopic three-dimensional visualization: interest for neuroanatomy teaching in medical school

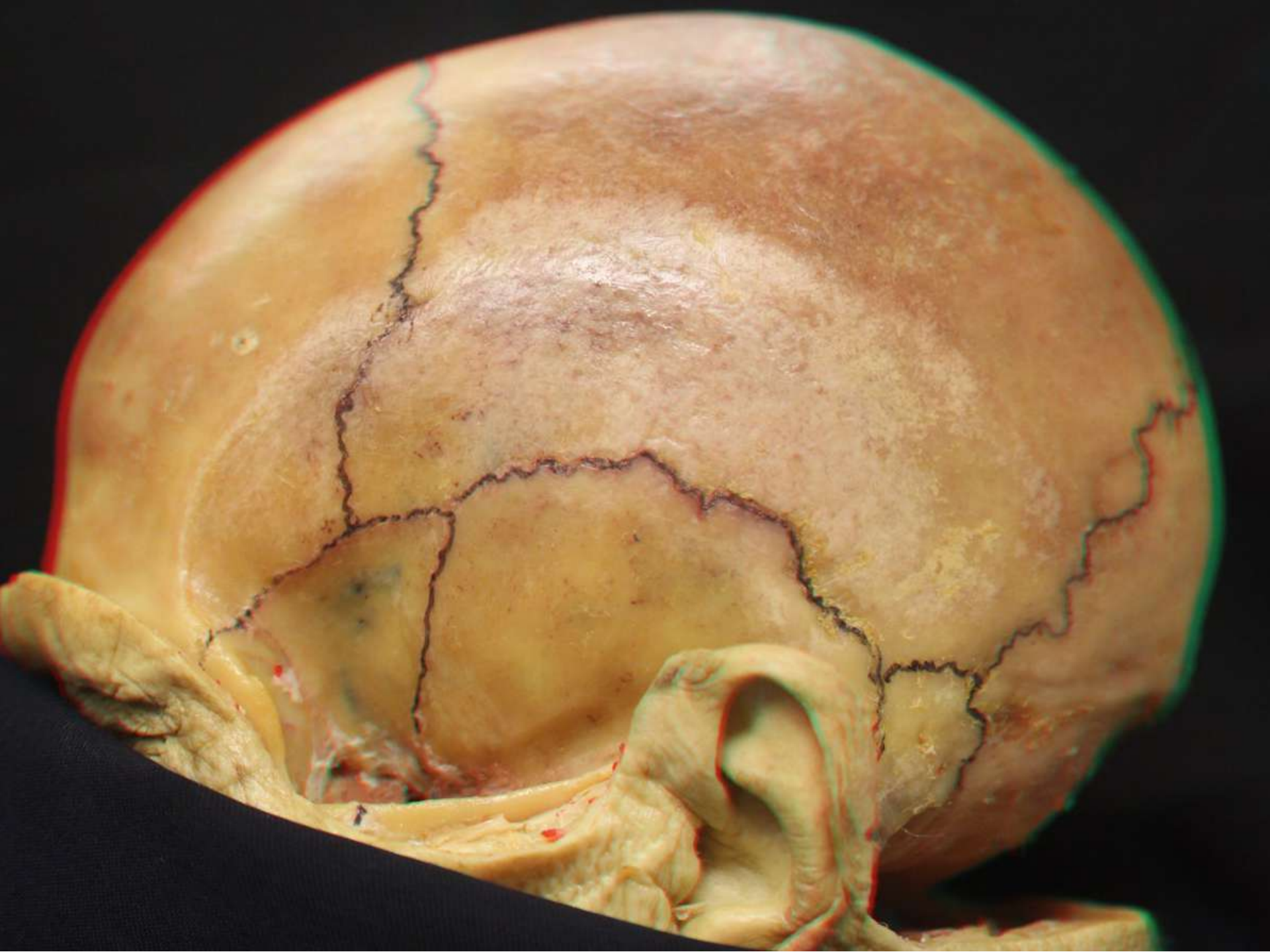
Timothée Jacquesson[1,2] · Emile Simon[1,4] · Corentin Dauleac[1] · Loïc Margueron[1] · Philip Robinson[3] · Patrick Mertens[1,4]

Received: 30 January 2020 / Accepted: 10 February 2020 / Published online: 29 February 2020

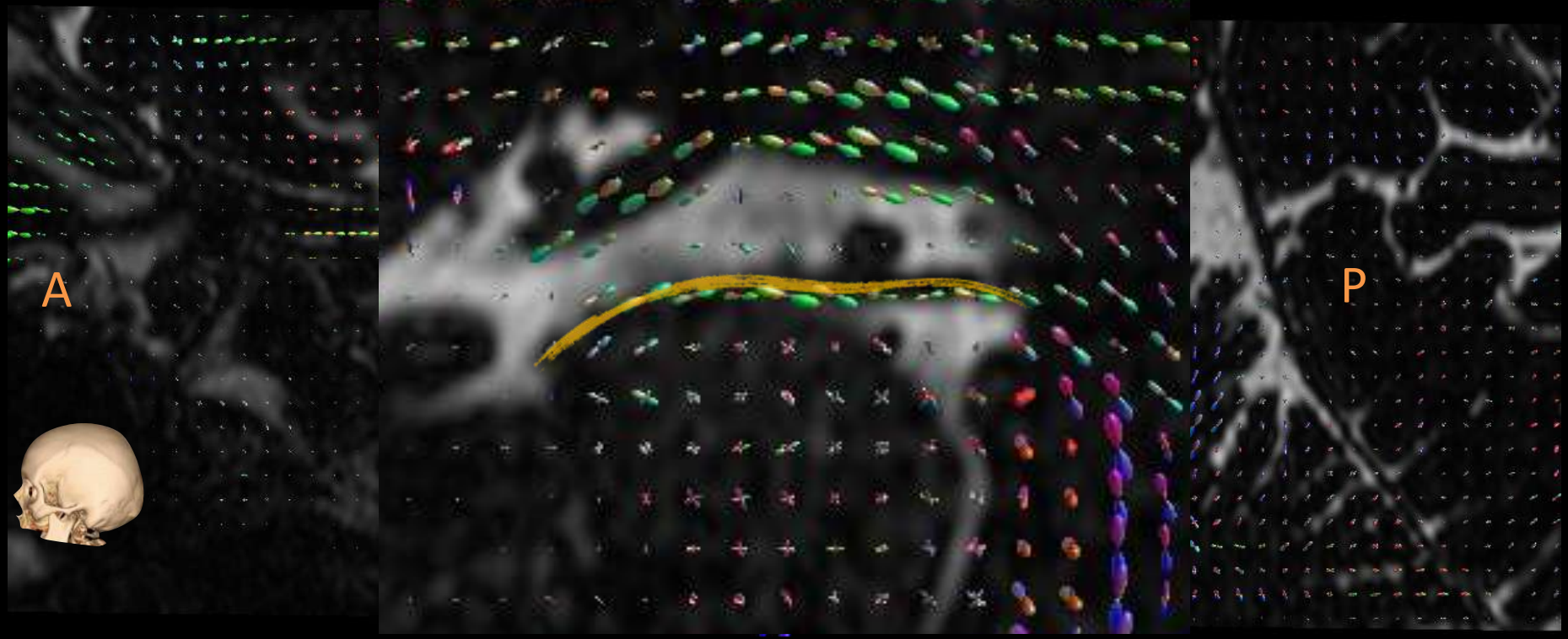




CREATIS



4.a IRM T2 HR



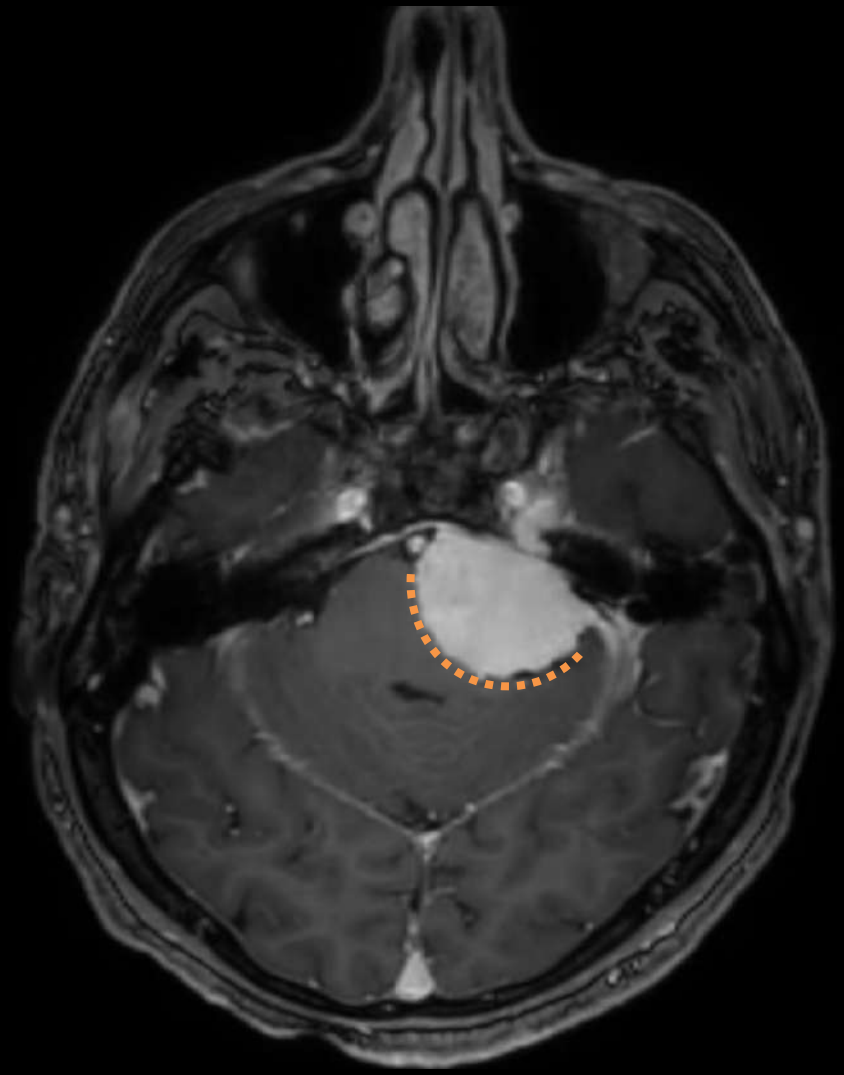
4.a IRM T2 HR

Personal data – T2 CISS cerebral MRI axial slice

4.a IRM T2 HR

Clivabilité ?

R



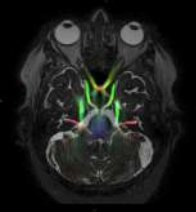
L

Personal data – T2 CISS cerebral MRI axial slice

4.a IRM T2 HR

consistance ?

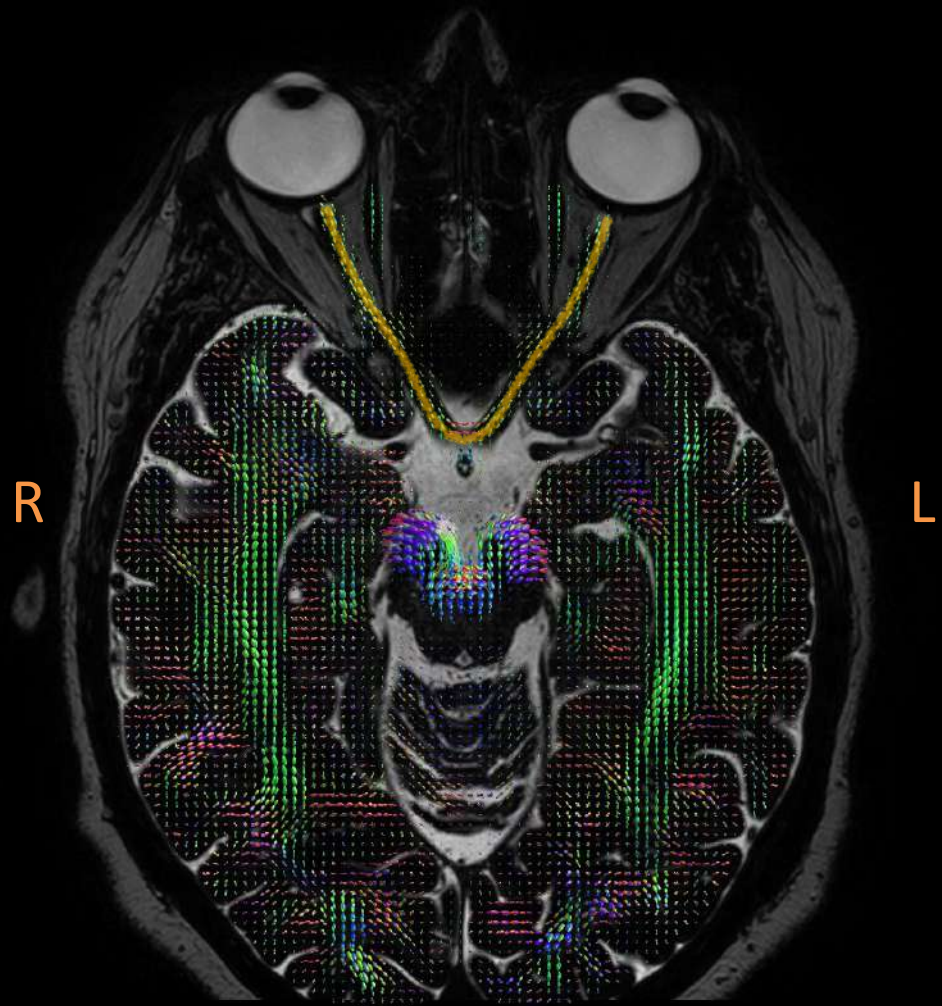
Personal data – T2 CISS cerebral MRI axial slice



4.a IRM T2 HR

ODF based analysis ?

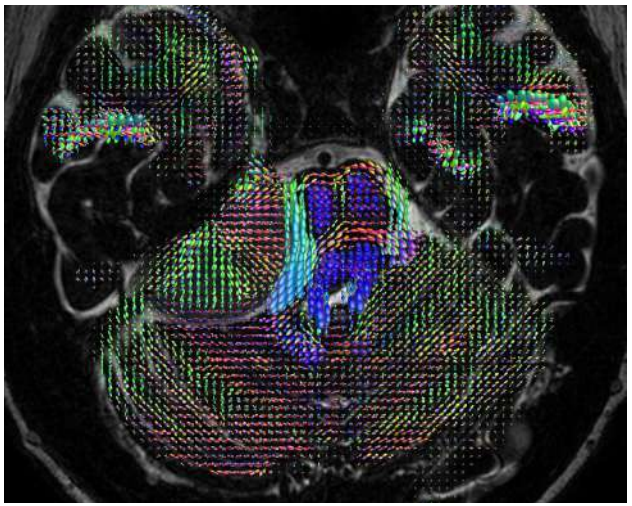
R



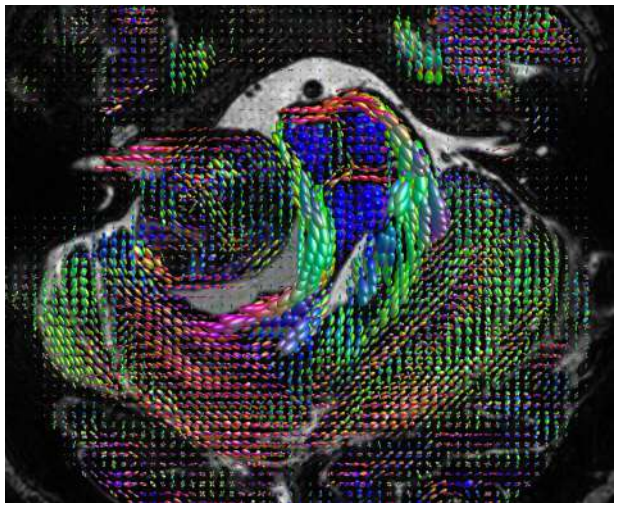
L

Personal data – ODF on T2 CISS cerebral MRI axial slice

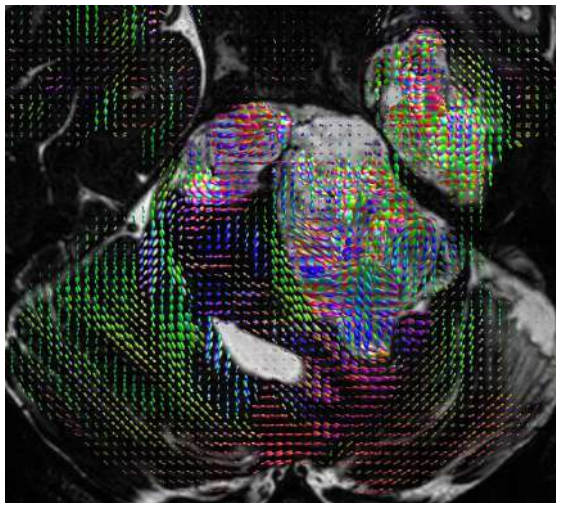
4.b Signature tumorale



Méningiome
Signal ODF **centripète**

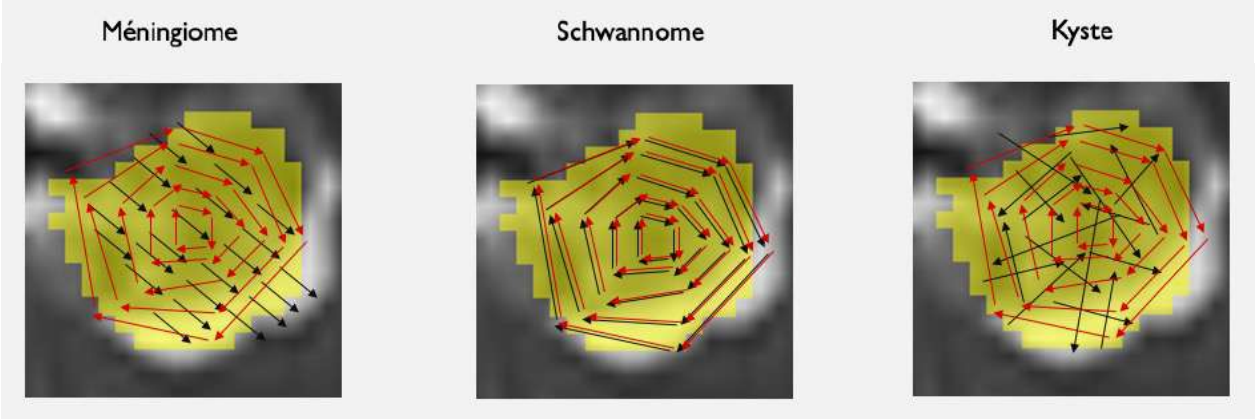


Schwannome
Signal ODF **rotatif**



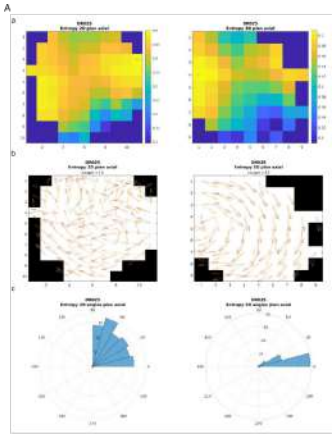
Kyste épidermoide
Signal ODF **anarchique**

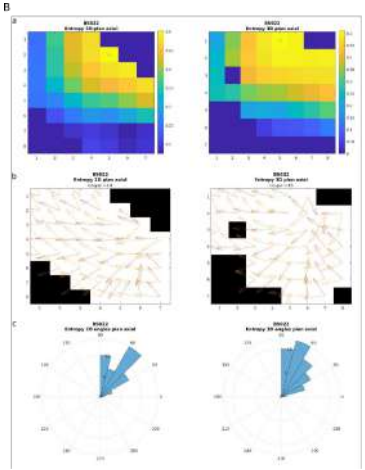
4.b Signature tumorale



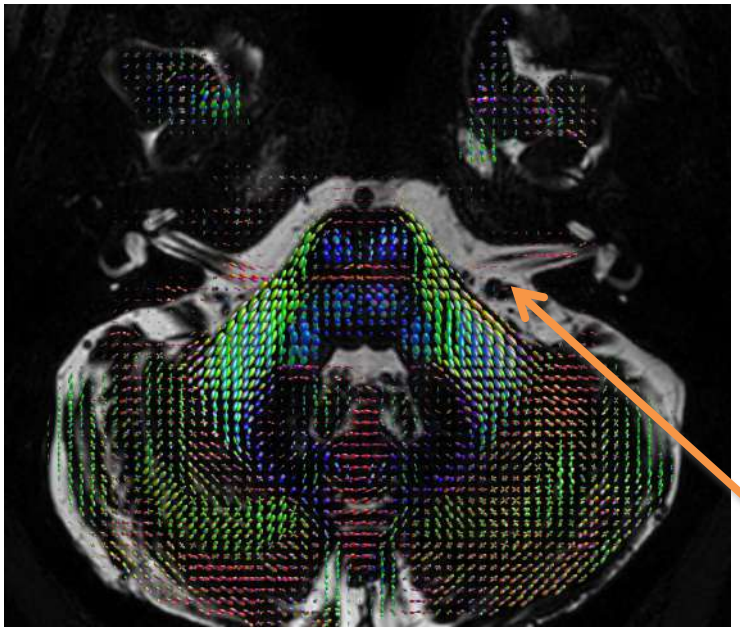
La diffusion des molécules d'eau peut être la **signature du tissu tumoral** et de la manière dont il s'organise lors du développement de la tumeur.

- > Confirmer l'hypothèse et construire des **descripteurs experts** capables de distinguer cette différence de signature.

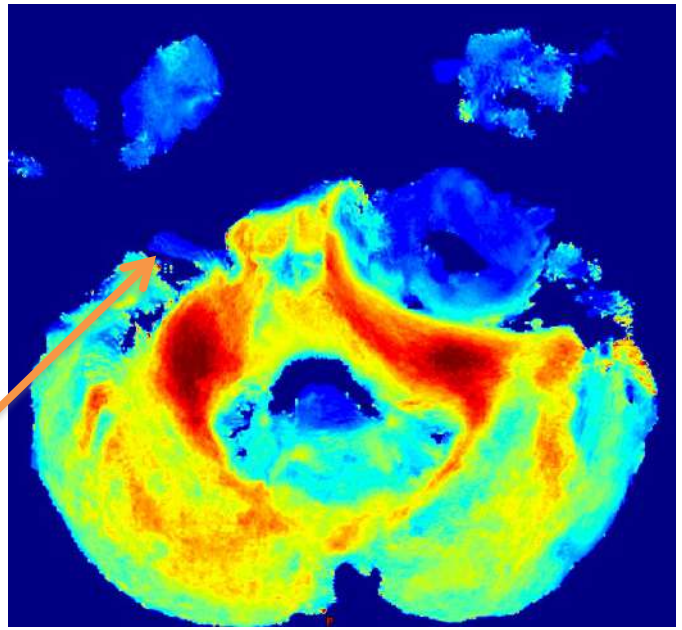




4.b Track density imaging



Personal data – FOD map



Personal data – TDI map

- Intérêt de la **Probabilistic Global tractography** ?
  -> compétition cerveau / nerfs crâniens
  -> grande amplitude FOD pour les fibres du cerveau
  -> reconstruction au détriment des nerfs crâniens

4.c Automatisation

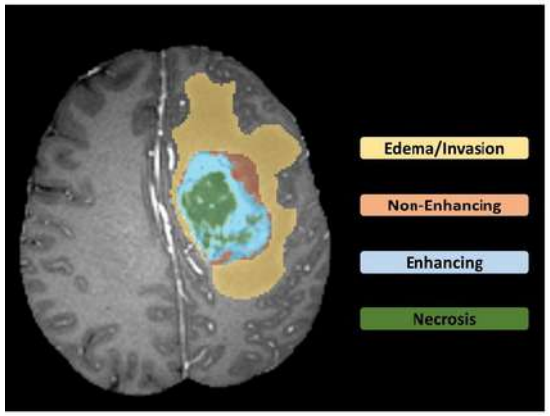


image T1gd pré-traité :

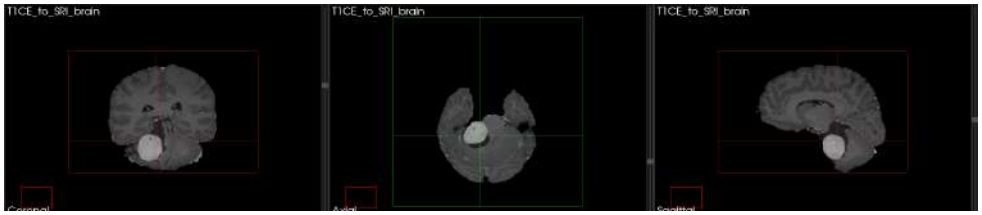
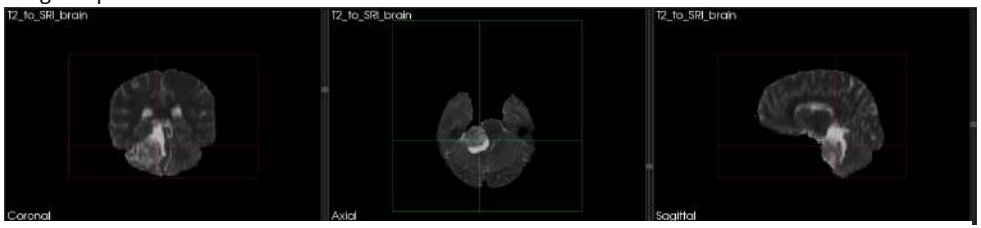
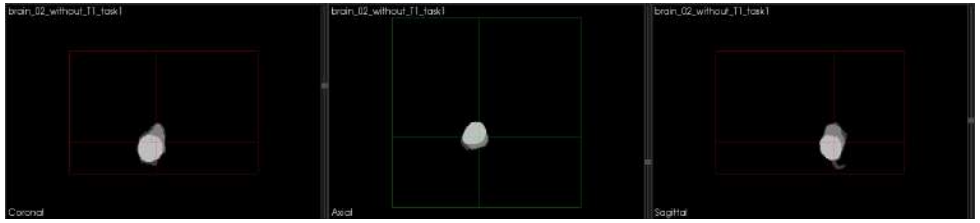


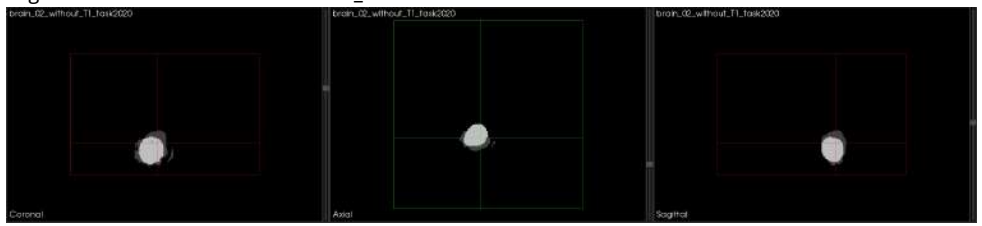
image T2 pré-traité :



Segmentation nnU-Net segmentation avec Task001_BrainTumour



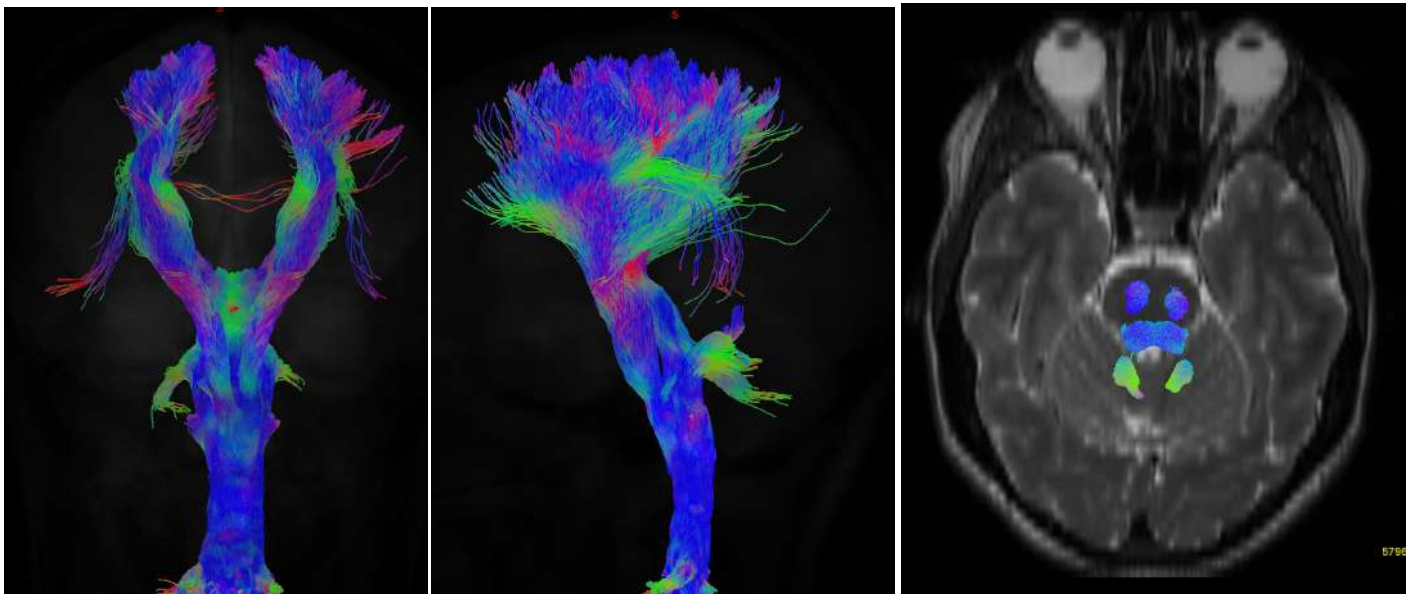
Segmentation nnU-Net avec Task082_BraTS2020



Task001_BrainTumour = modèle le plus pertinent si on a les 4 modalités d'image
Task082_BraTS2020 = meilleur avec 2 modalités
A confirmer sur plus de patients avec données T1, T1G, T2 et T2 FLAIR homogènes

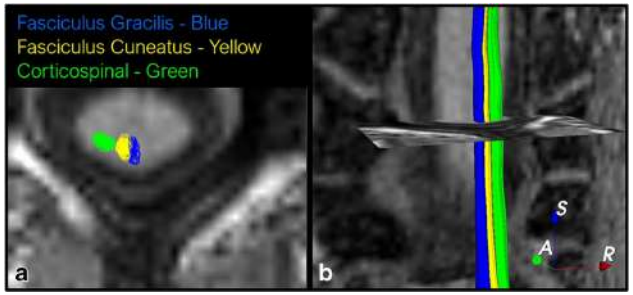
CREATIS

4.e Spinal cord White Matter



Personal data – in progress

- Optimisation des données acquisition & post-traitement
- Amélioration résolution spatiale
- Lien avec connectivité cérébrale
- Création d'un atlas des faisceaux de la moelle spinale
- Superposition des données patient dans un espace normalisé



McLachlin et al., 2021

4.a Réalité augmentée

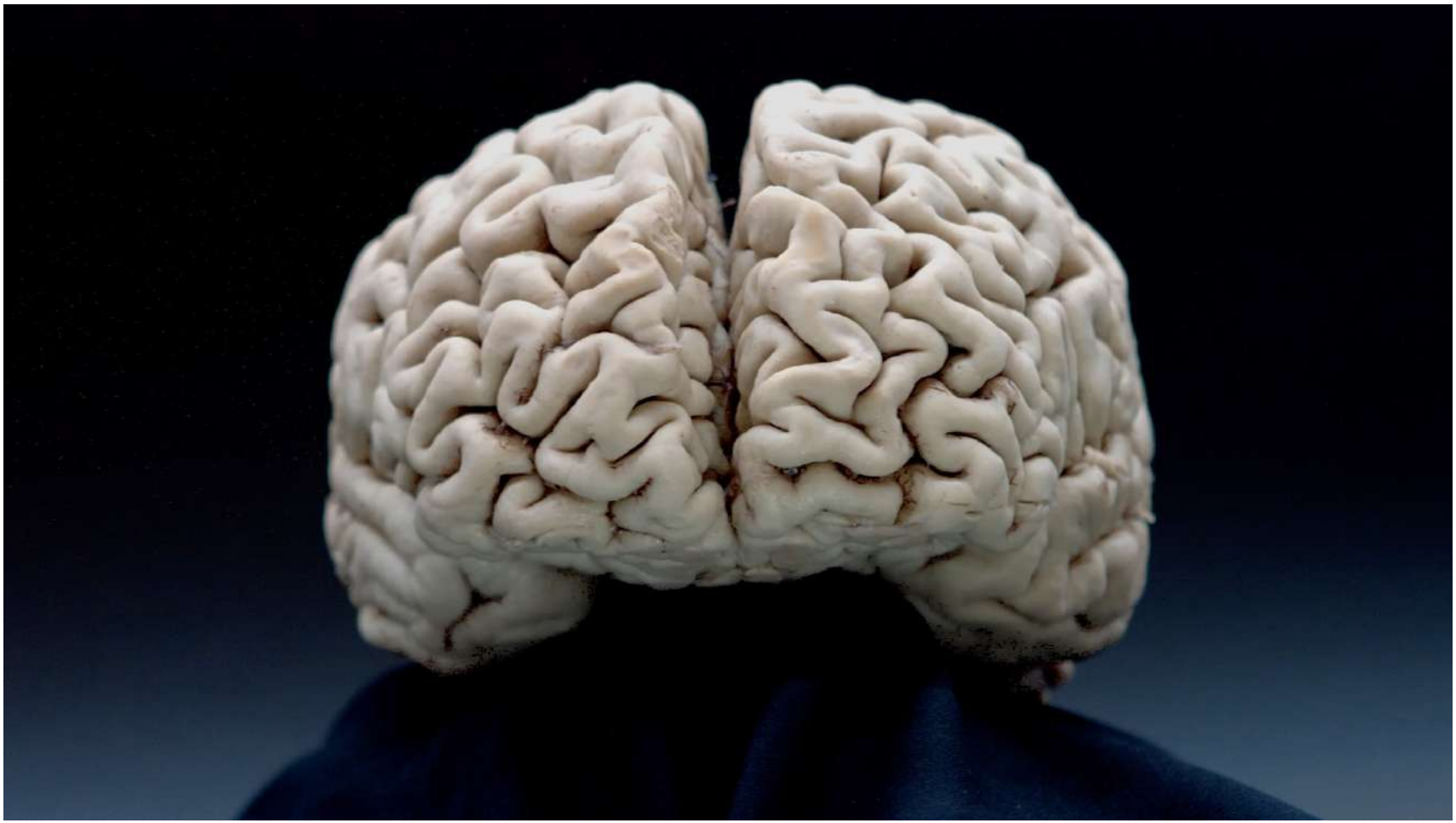
www.microsoft.com

Upsurgeon® devices

Transfert clinique de la tractographie
& Intégration au bloc opératoire de l'imagerie

- En **Réalité augmentée** et/ou virtuelle
- **Superposition** des informations pertinentes en temps réel
- **Simulation** chirurgicale mental/manuel/hybride

4.a Anatomie chirurgicale



- Recherche en **pédagogie** : Parcours **Mooc** validant en Neuroanatomie

Morgane DES LIGNERIS
2021-2022
Segmentation automatique / Signature histologique

Tiffany NOSREE
2021-2022
T2 versus Tractographie

Justine BOSC
2016-2017
Optimisation / Validation

Méghane DECROOCQ
2017-2018
Point de vue / Filtrage

Corentin DAULEAC
2018-2019
Tractographie Moelle spinale

CREATIS

Remerciements

Arnaud ATTYE

Claire BOUTET

Marc BRAUN

CREATIS

Remerciements

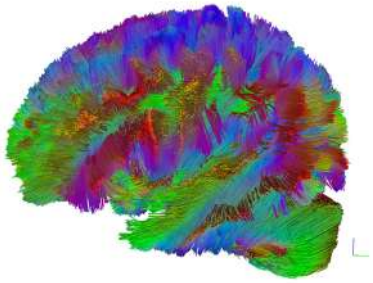
Evelyne EMERY

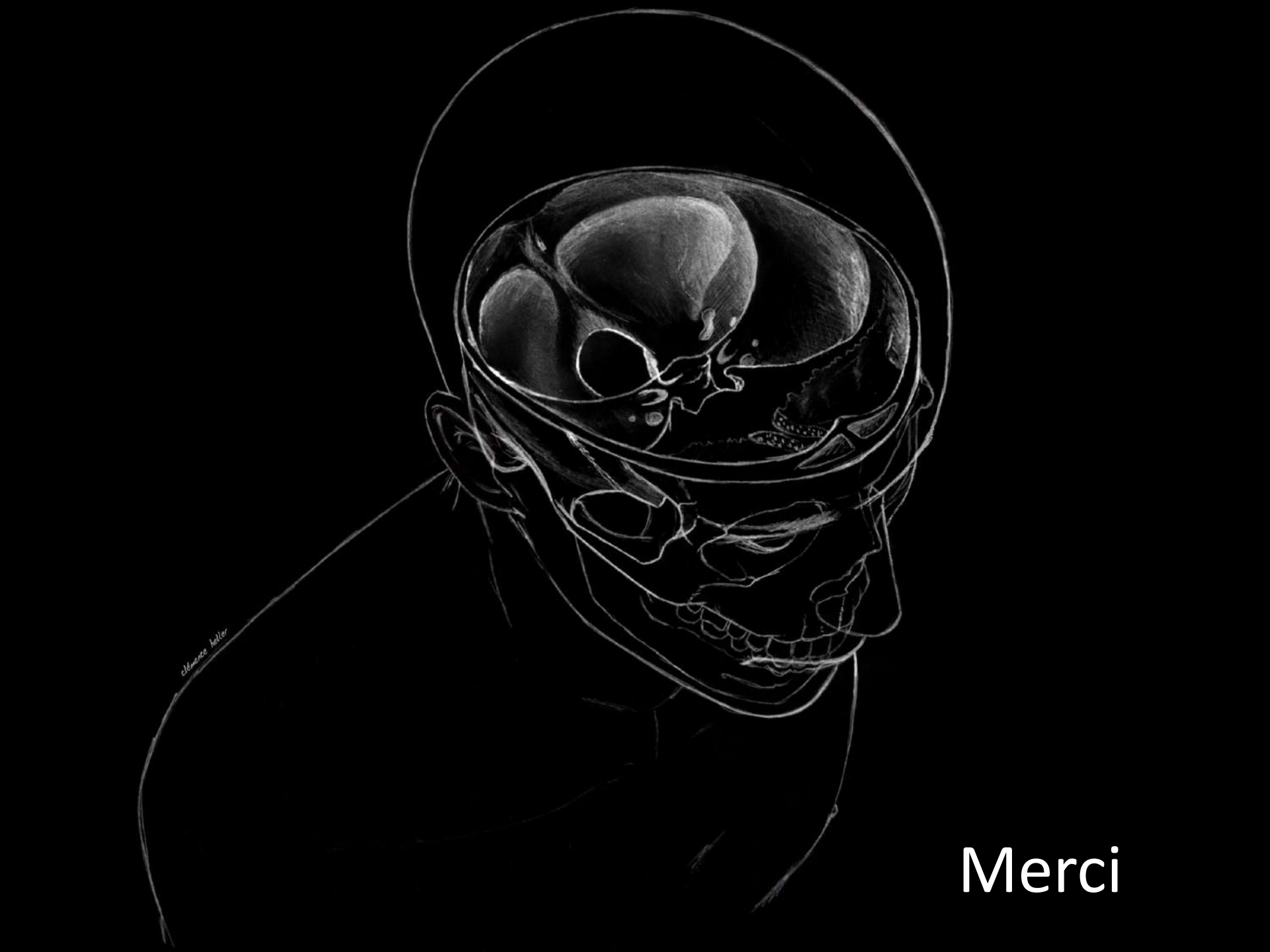
Carole FRINDEL

François COTTON

Patrick MERTENS

Emmanuel JOUANNEAU




Merci