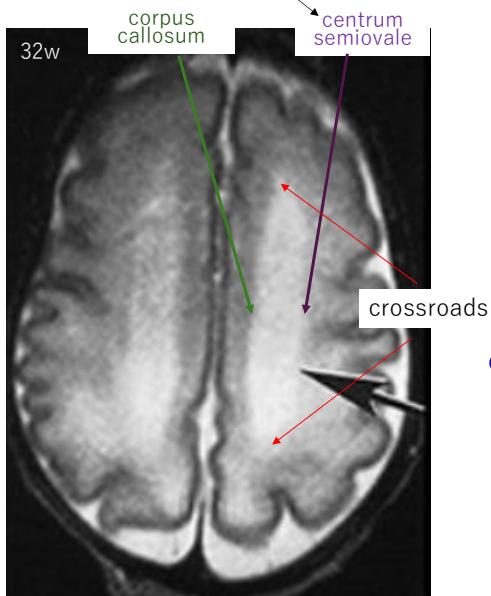


胎児期白質分化－2

横地健治

1

Kostvicはcentrum semiovaleと言うが
corona radiataに言い換えた



3c領域

- crossroads 定義がない
- corpus callosum
隣接するcingulumとの異同が問題
- corona radiata
centrum semiovale
包括的呼称で解剖学的実体が曖昧

3c領域の呼称は止め



corona radiata・cingulum complex (CR・Cn複合)

- cingulum
- sagittal stratum-後方corona radiata複合
- 前方corona radiata
- 上方corona radiata

2

Compartmental organization of the brain with related axonal pathways.

Deep (periventricular) compartment

- Corpus callosum – (segment I)
- Fronto-occipital fascicle (FOF) – (segment I)
- Cortico-striatal fibers (Muratoff's fascicle) – (segment I)
- Fronto-pontine pathways – (segment I)

Intermediate compartment

- Crossroads of projection pathways – (segment II) IIa
 - Thalamocortical fibers
 - Cortico-fugal fibers
 - Callosal radiation
 - Associative sagittal fibers

Sagittal axonal strata – (segment II)IIb

- Thalamocortical pathways
- Basal forebrain cholinergic afferents
- Cortico-cortical associative fiber system

Centrum semiovale – (segment III)

- Long associative fiber system
- Projection fibers

Superficial compartment

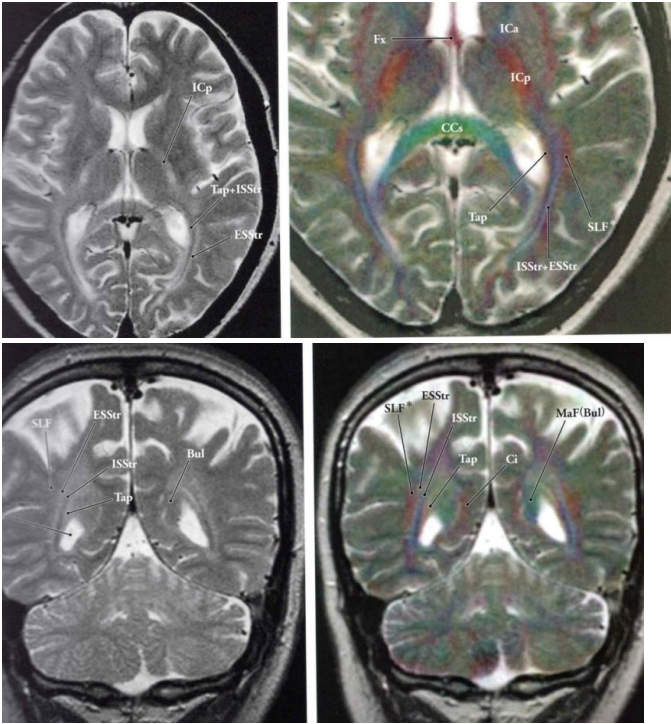
- Gyral white matter – (segment IV)
 - Short cortico-cortical fibers
 - U-fibers
- Subplate/subplate remnant
 - Growing front of all afferent pathways
 - Short cortico-cortical fibers
- Intracortical fibers – (segment V)

大脳白質の発達の区分

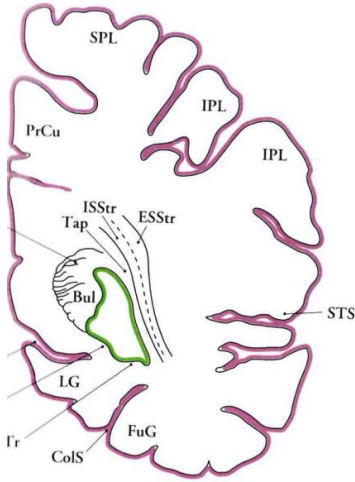
Kostović I et al. Developmental dynamics of radial vulnerability in the cerebral compartments in preterm infants and neonates. Front Neurol . 2014;5:139.

Crossroads Sagittal strata				
Von Monakow のsegment	Deep periventricular	Intermediate		Distal (superficial)
Compartments (where?)	Segment I (periventricular pathway)	Segment II (crossroads and sagittal strata)	Segment III (centrum semiovale)	Segment IV and V (gyral white matter and cortical white matter) Subplate
Axonal pathways classes (what?)	Callosal, associative (FOF) and motor (corticostriatal and corticopontine)	Sensory (thalamocortical) Motor (pyramidal)	Long associative (FLS, FA, FLI, etc.) Sensory	Short cortico-cortical (U fibers) Intracortical
Schematic representation of pathways (connectivity)				

3



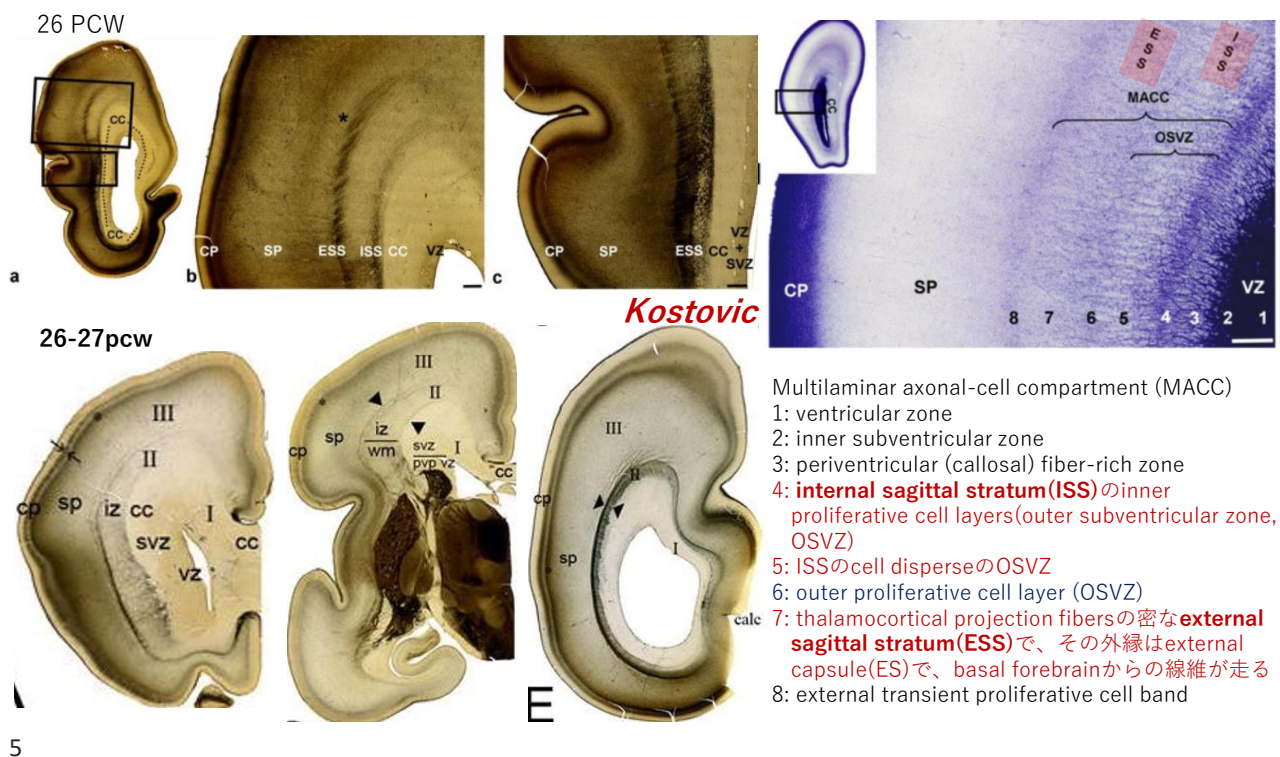
脳MRI 1. 正常解剖 第2版 高橋昭喜編著



ESStr: external sagittal stratum T2高信号
ISStr: internal sagittal stratum

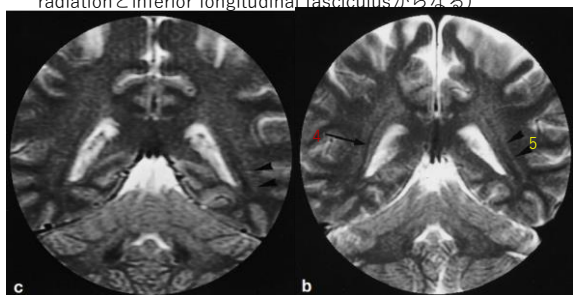
MaF: major forceps Tap: tapetum Ci: cingulum

4



Hosoya T, et al. MRI anatomy of white matter layers around the trigone of the lateral ventricle. *Neuroradiology* 1998; 40:477-82.

tapetum: corpus callosumの一部
internal sagittal stratum: corticocortical tract
external sagittal stratum: geniculocalcarine tract (optic radiationとinferior longitudinal fasciculusからなる)



T2
6層構造 組織学的実体は不明
内側→外側
1. tapetum
2. medial sagittal lamina
3. internal sagittal stratum T2では低信号
4. **central sagittal lamina**
5. external sagittal stratum T2は、皮質下白質より高信号
6. lateral sagittal lamina

Kitajima M, et al. MR signal intensity of the optic radiation. *AJNR Am J Neuroradiol* 1996;17:1379-83.

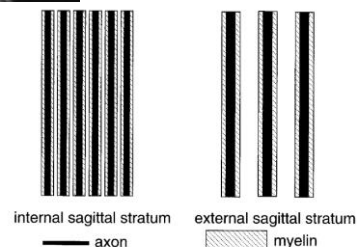
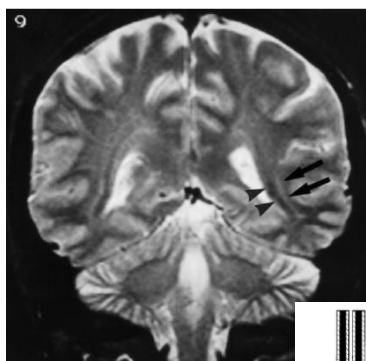


Fig 4. Histologic characteristics of the external sagittal stratum and the internal sagittal stratum. The external sagittal stratum has large axons, thick myelin sheaths, and wide translucent spaces. In contrast, both axons and myelin sheaths of the internal sagittal stratum are small and associated with narrow translucent spaces.

Jella PK, et al. Quantifying Tissue Properties of the Optic Radiations Using Strategically Acquired Gradient Echo Imaging and Enhancing the Contrast Using Diamagnetic Susceptibility Weighted Imaging. *AJNR Am J Neuroradiol* 2021;42:285-287.

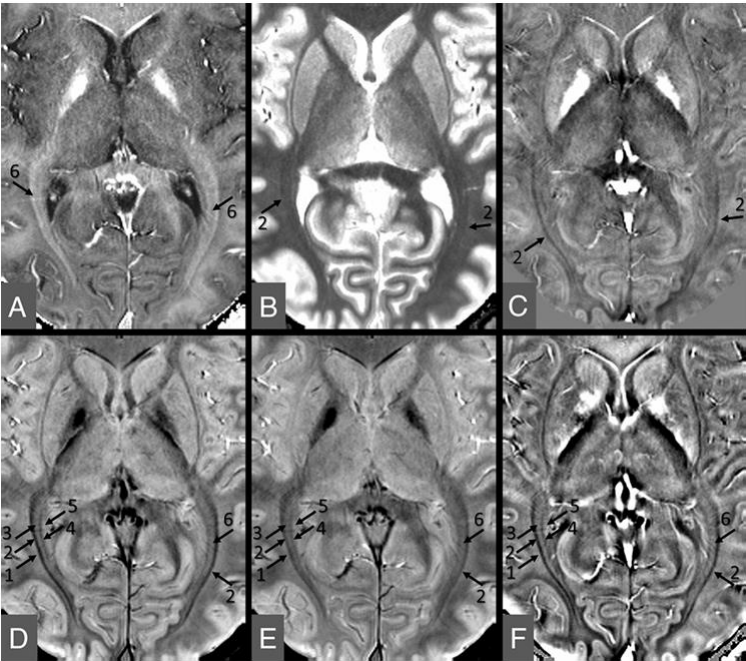
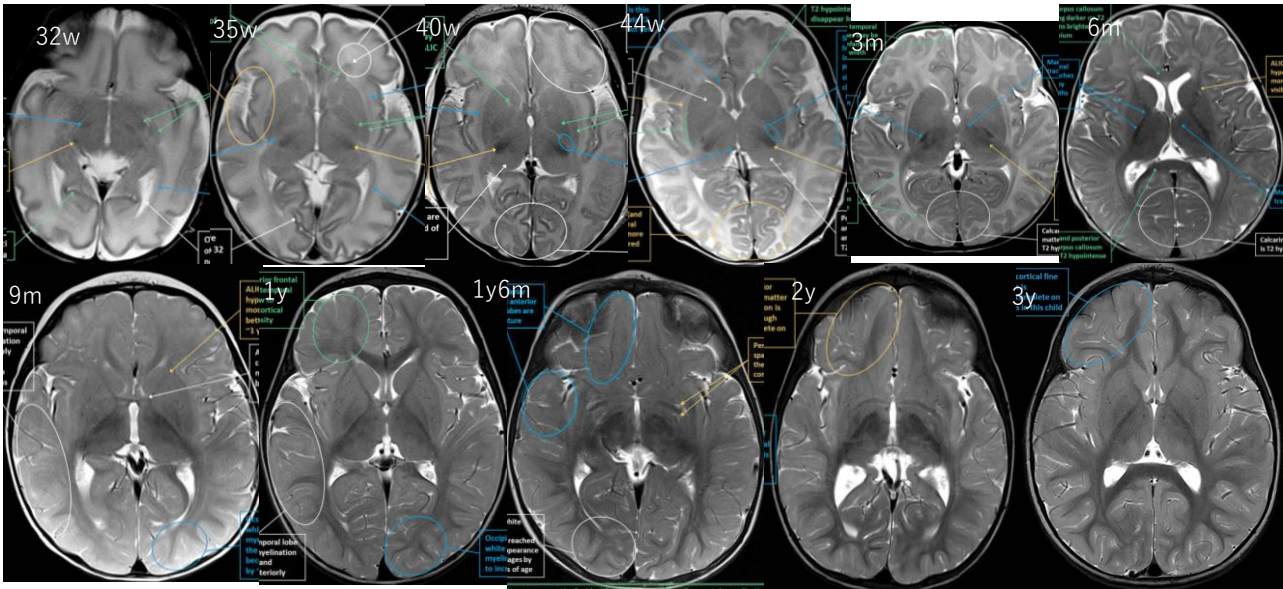


FIGURE. Example images used for evaluating the ORs from a representative case (a 32-year-old woman). A, R2* map. B, T1 map. C, QSM. D, dSWI. E, T2*-PD-weighted image. F, HPF phase image. The T2*-PD-weighted and dSWI show the best contrast for visualizing the ORs, in which the ESS and TAP (black arrows 2 and 4) can be identified. In D and E one can see 5 bundles: the outer WM layer (arrow 1), the ESS (arrow 2), the ISS (arrow 3), the TAP (arrow 4), and the inner WM (arrow 5) layer. Also, for the T2*-PD-weighted (E), R2* (A), dSWI (D), and HPF phase data (F), there is evidence of veins cutting across the 5 bundles (arrow 6).

- 1: outer white matter
- 2: external sagittal stratum
- 3: internal sagittal stratum
- 4: tapetum
- 5: inner white matter
- 6: veins

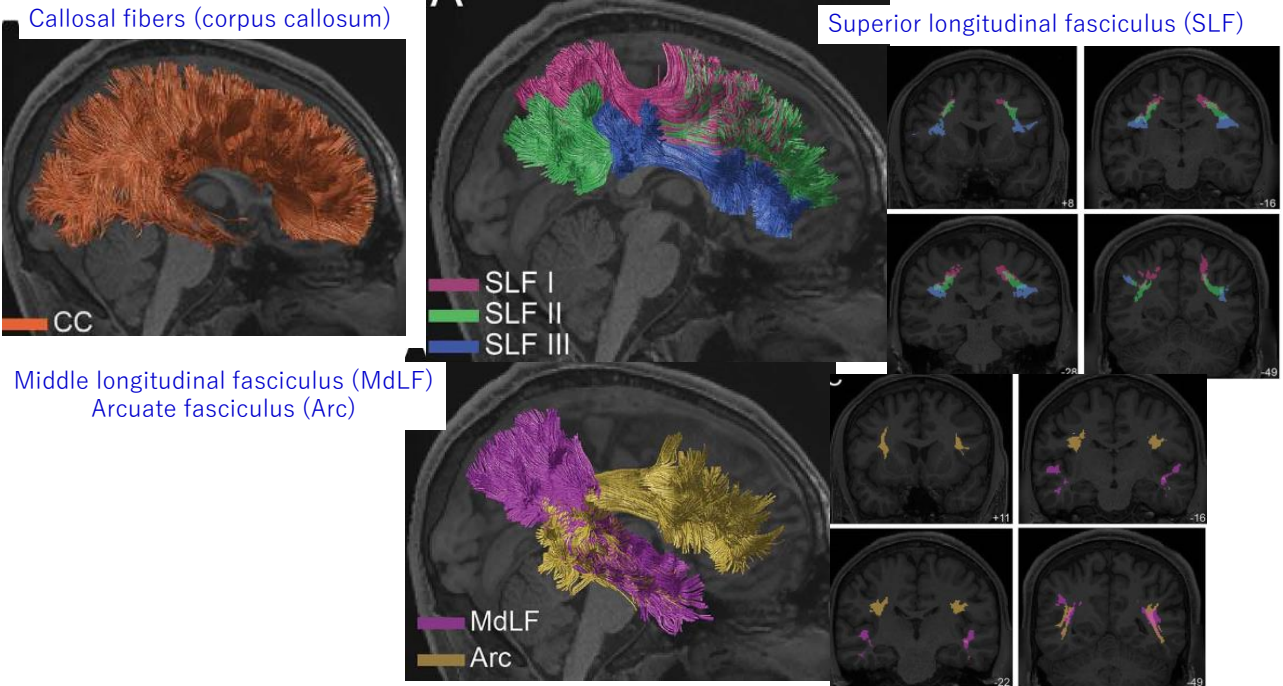
dSWI = diamagnetic susceptibility weighted imaging; ESS = external sagittal stratum; ISS=internal sagittal stratum; OR=optic radiation; STAGE=strategically acquired gradient echo; TAP=tapetum; HPF=high-pass-filtered; QSM=quantitative susceptibility map; PD=proton density

7

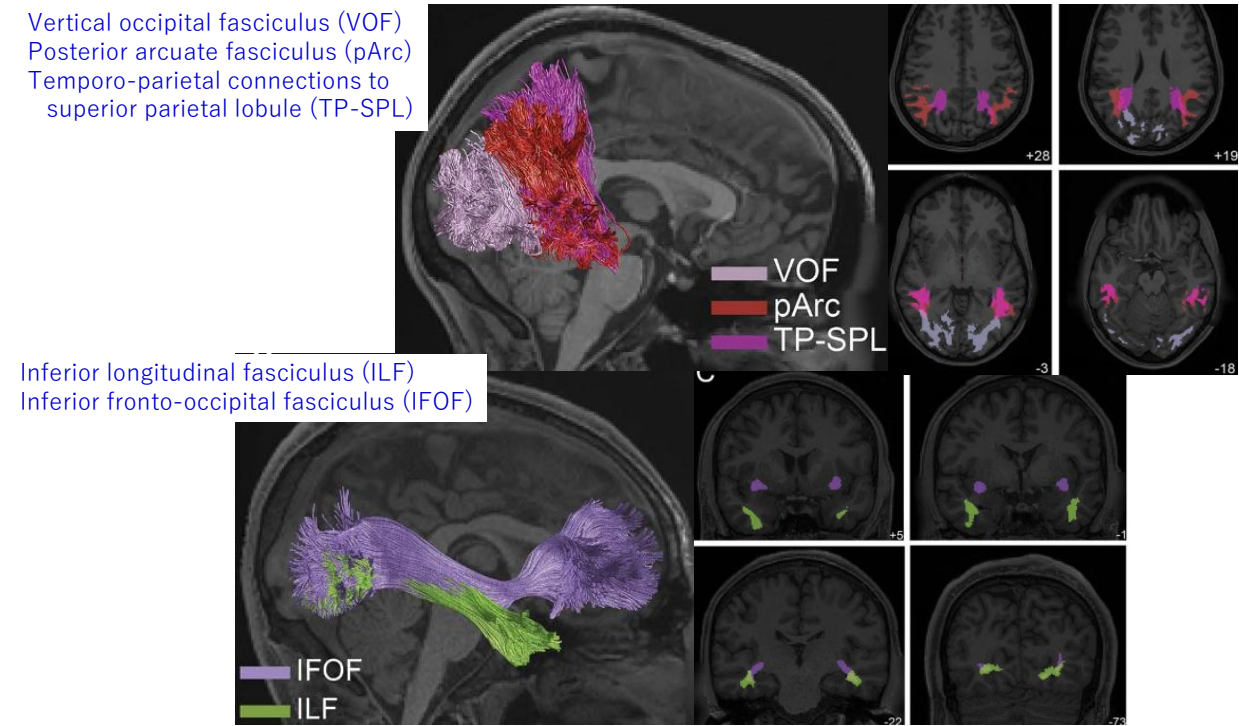


Matsumoto JA. et al. *MRI Atlas of Pediatric Brain Maturation and Anatomy*. Oxford University Press. 2015.

8

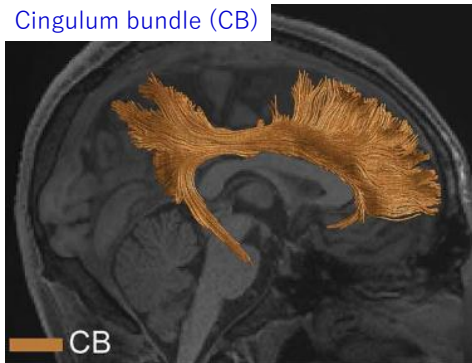


9

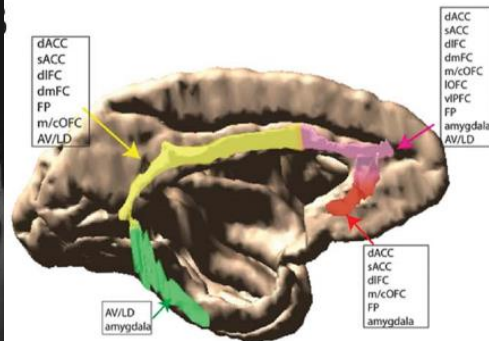
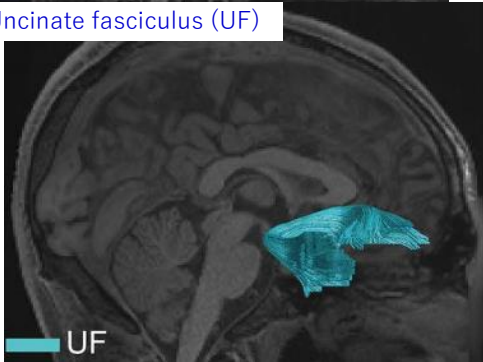


10

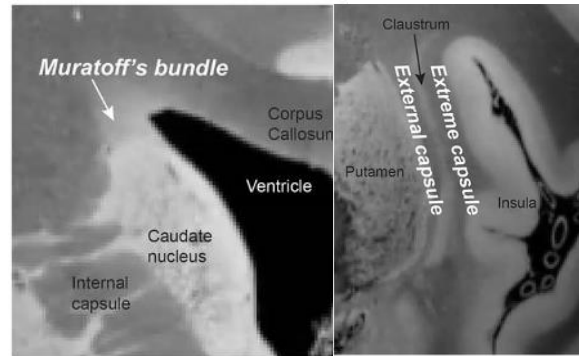
Cingulum bundle (CB)



Uncinate fasciculus (UF)

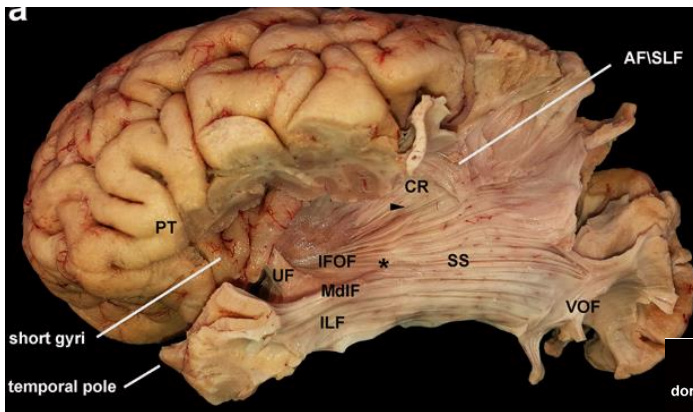


Cortico-striatal connections
Muratoff's bundle
External capsule



11

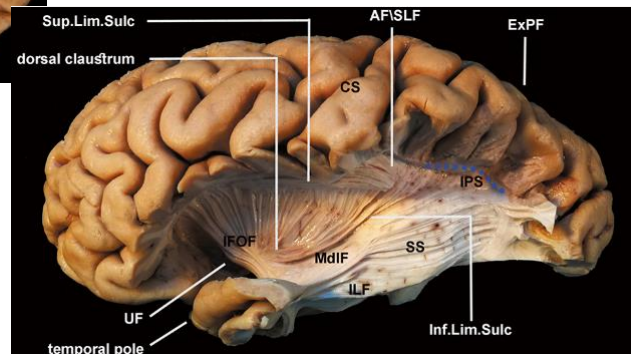
Di Carlo DT, et al. Microsurgical anatomy of the sagittal stratum. Acta Neurochir (Wien) 2019;161:2319-2327.



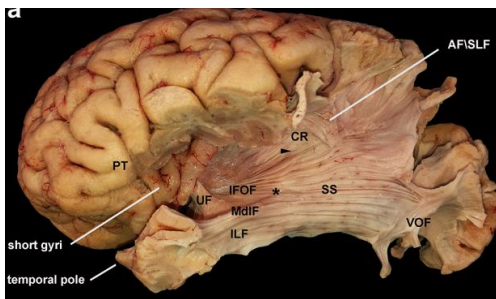
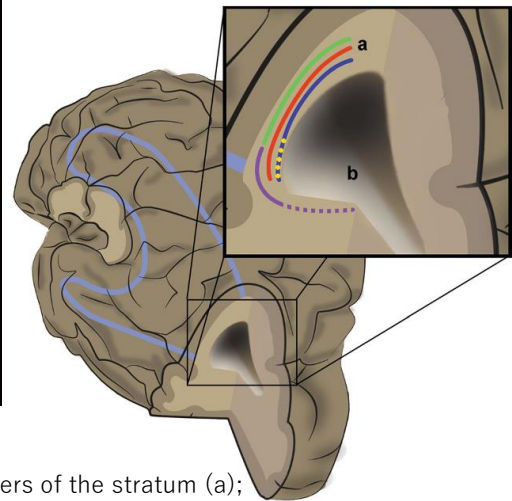
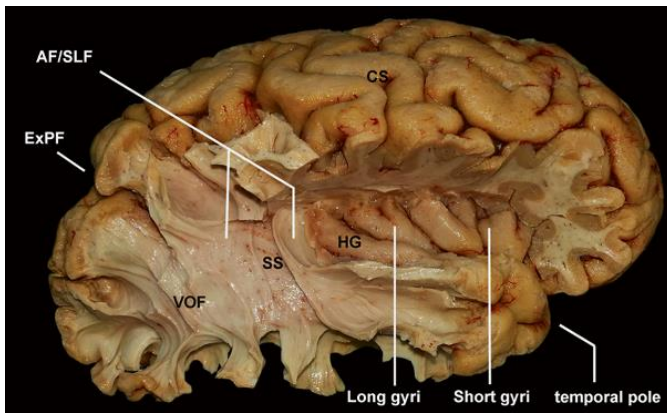
- MdlFとIFOFの交点(*)がSSの前縁
- VOFがSSの後下縁
- SSは島後部でCRとつながる
- AF/SLF がSSの外縁
- SSはAF/SLF complexの下を後部頭頂葉に走る

- ILFはSSの下を走る

CR: corona radiata
IFOF: inferior fronto-occipital fascicle
ILF: inferior longitudinal fascicle
MdlF: middle longitudinal fascicle
VOF: vertical occipital fascicle
SS: sagittal stratum
UF: uncinate fascicle
AF: arcuate fascicle
SLF: superior longitudinal fascicle



12



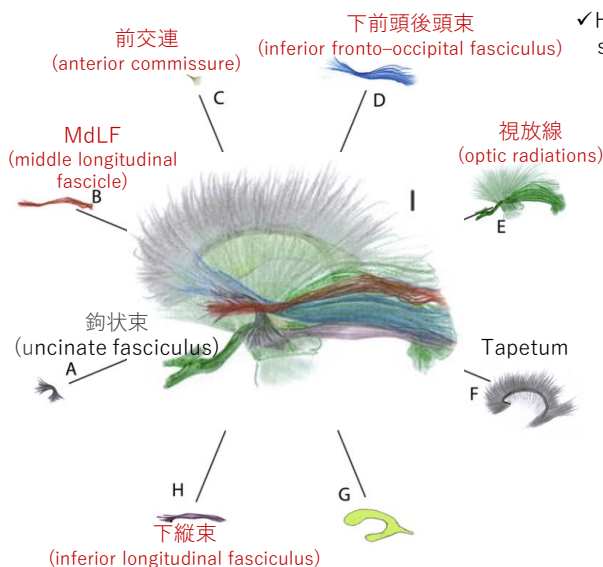
The three layers of the stratum (a); the superficial layer is formed by the MdLF (green line), and the dorsolateral occipital portion of the ILF (violet—continue line); the middle layers are formed by the IFOF (red line); the deep layer is formed by the OR(optic radiation, blue line), intermingled in its inferior part with the AC (anterior commissure, yellow spots)

MdLF・ILF・IFOF・OR・ACはSSの構成要素

13

Maldonado IL, et al. Composition and organization of the sagittal stratum in the human brain: a fiber dissection study. J Neurosurg 2021;135:1214-22.

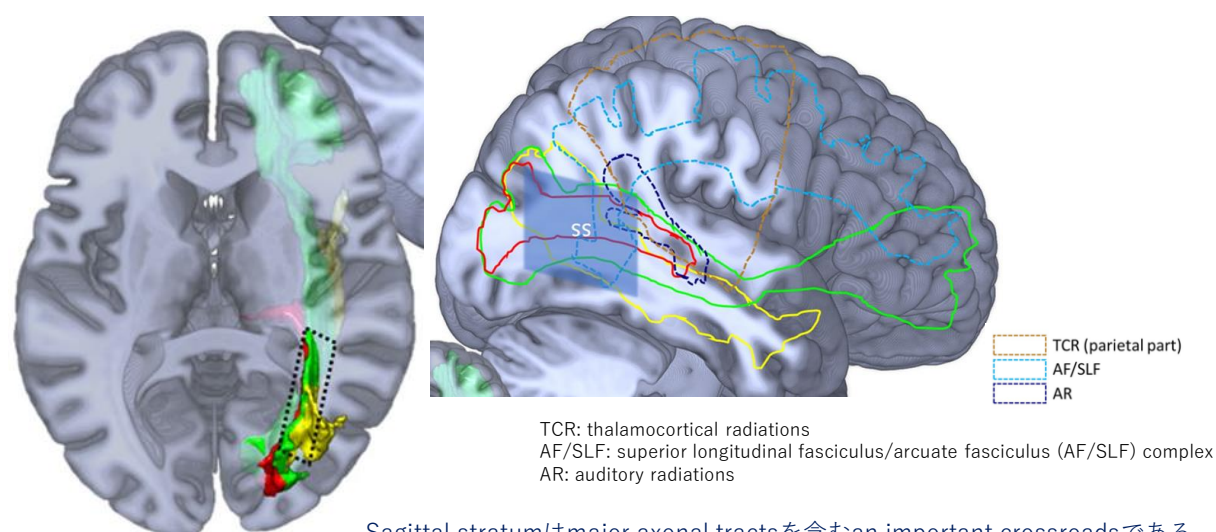
Sagittal stratum (ss)



✓Heinrich Sachs (1892) 三角部・後角周囲白質を命名 stratum sagittale internum (optic radiation)とexternumに二分

- SSは、外側は上縦束(superior longitudinal fasciculus)/弓状束(arcuate fasciculus)複合で、内側はtapetumにある全白質を指す (この両者はSSに含めない)。概ね水平方向の線維走行である
 - ・ SLFはsuperior corona radiataの外側にある
 - ・ tapetumはposterior corona radiataの内側にある
- ・ 鉤状束(海馬由来)がSSの前縁となる
- ・ 下縦束(ILF, 側頭葉下面)がSSの腹側縁となる
- ・ SSの背側と後側はcorona radiataと連続する *境界は不定
sagittal stratumとcorona radiataは別物
- ・ MdLF(後頭葉と側頭葉・頭頂葉をつなぐ)はSS外側層の背側部をなす
- ・ 前交連の線維束は、下前頭後頭束と弓状束と被われる
- ・ 下前頭後頭束の後方部はSSに合体し、三角部・後角の主な線維束となる。さらに後方では、視放線に入る
- ・ SS内側層は視放線を含む。Thalamic posterior radiationsと同一面にあり。Tapetumを被う
- SSはB-EとHの平面

14



Sagittal stratumはmajor axonal tractsを含むan important crossroadsである

- IFOF: inferior fronto-occipital fasciculus
- OR: optic radiations
- ILF: inferior longitudinal fasciculus
- MLF: middle longitudinal fasciculus

3層からなる
 deep layer: OR
 middle layer: IFOF
 superficial layer: ILF, MLF

境界
 前縁: IFOFとMLFの境界
 下縁: ILFの背外側後頭部
 後縁: vertical occipital fascicule
 外縁: SLF/AF

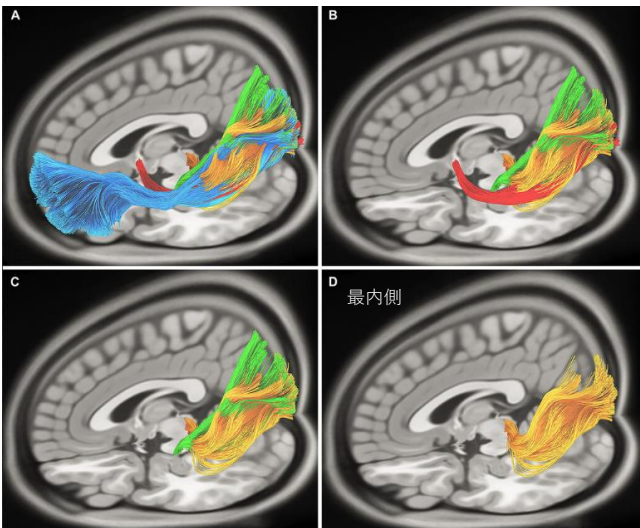
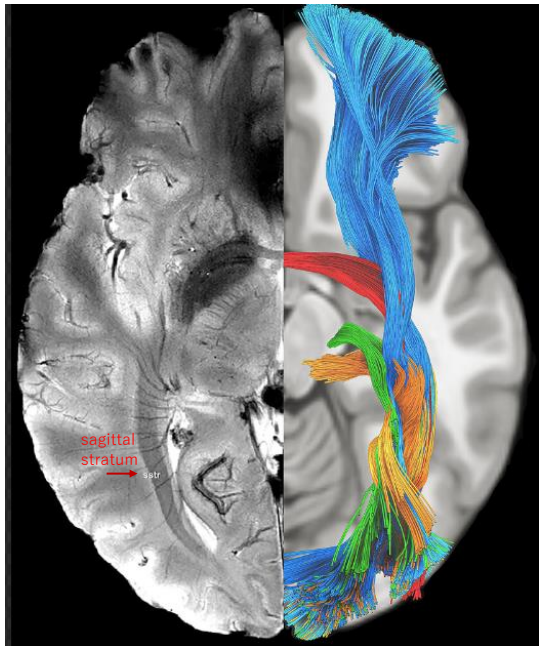
Berro DH, et al. New insights into the anatomo-functional architecture of the right sagittal stratum and its surrounding pathways: an axonal electrostimulation mapping study. Brain Struct Funct 2021;226:425-441.

15

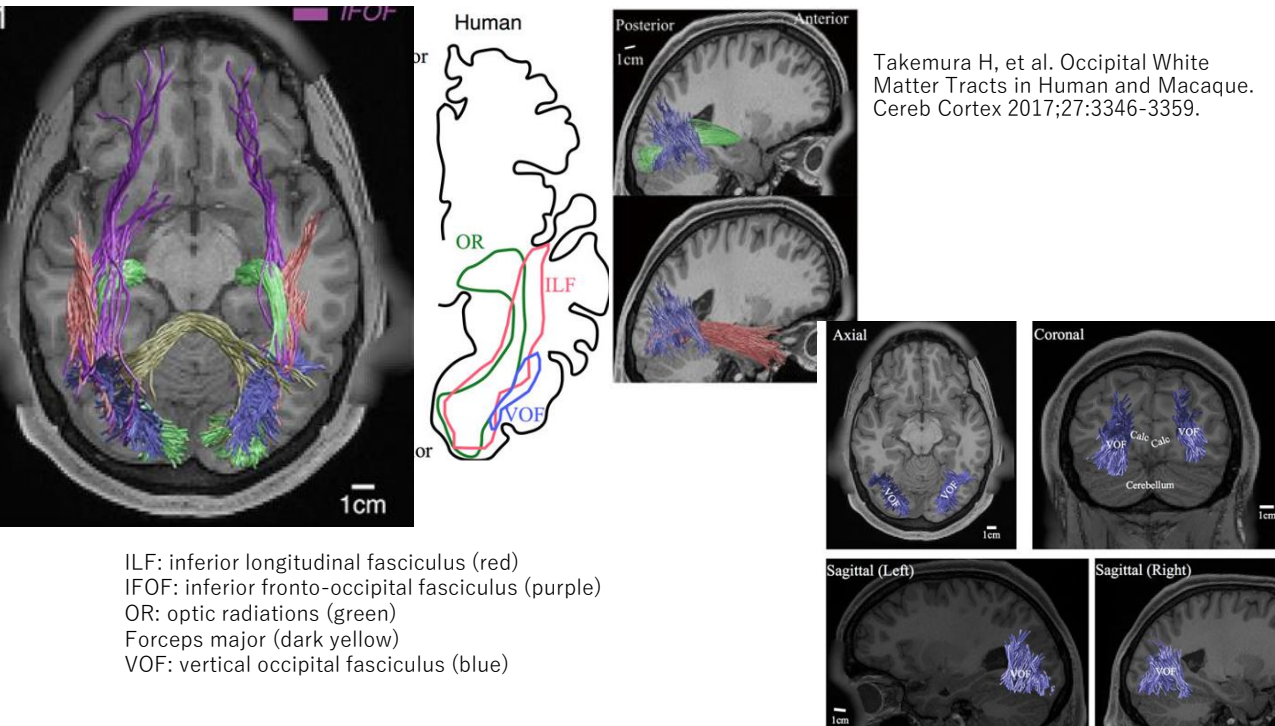
Gülsuna B et al. Revisiting the microsurgical anatomy of the sagittal stratum and surgical implications: fiber microdissection and tractography study. J Neurosurg 2024;1-14.

sagittal stratumは以下からなる

- Posterior thalamic peduncle (yellow)
- Temporo-parieto-occipito-pontine fibers (green)
- Anterior commissure (red)
- Occipitofrontal fasciculus (blue)



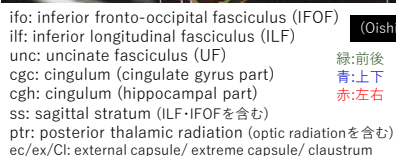
16



17

Goga & Tune (2015)	The sublenticular portion of the internal capsule, lateral extension of anterior commissure, and occipitofrontal fasciculus become interwoven and follow a joint course to the temporal and the occipital regions as the compact sagittal stratum.	Occipitofrontal fasciculus Anterior commissure Temporo-parieto-occipitopontine fibers Posterior thalamic peduncle
Yagmurlu et al. (2015)	The occipital and temporal projection fibers, called the sagittal stratum, are positioned medial in the occipital extension of the anterior commissure and the inferior occipitofrontal fasciculus and inferior longitudinal fasciculus.	Parietopontine fibers Occipitopontine fibers Optic radiation
Pescatori et al. (2017)	It is a structure that covers the side face and the roof of the temporal horn and atrium of the lateral ventricle from which it is separated by the descent fibers of the tapetum.	Parietopontine fibers Occipitopontine fibers Optic radiation
Di Carlo et al. (2019)	The sagittal stratum is a critical neural crossroad transversed by several white matter tracts that connect multiple areas of the ipsilateral hemisphere.	Anterior commissure Optic radiation Inferior fronto-occipital fasciculus Middle longitudinal fasciculus Inferior longitudinal fasciculus
Berro et al. (2021)	The sagittal stratum is a large, sheet-like, sagittal structure of white matter, located lateral to the superolateral wall of the temporal horn, the atrium, and the occipital horn of the lateral ventricle.	Optic radiation Inferior fronto-occipital fasciculus Middle longitudinal fasciculus Inferior longitudinal fasciculus
Maldonado et al. (2021)	The sagittal stratum includes all of the white matter located between the superior longitudinal fasciculus/arcuate fasciculus complex laterally and the tapetum medially.	Optic radiation Anterior commissure Inferior fronto-occipital fasciculus Middle longitudinal fasciculus Inferior longitudinal fasciculus
Caspers et al. (2022)	The sagittal stratum is a prominent and macroscopically clearly visible white-matter structure within occipital and parietal lobes with a highly organized structure of parallel fibers running in a rostro caudal direction.	Optic radiation Inferior longitudinal fasciculus Superior longitudinal fasciculus Fronto-occipital fasciculus

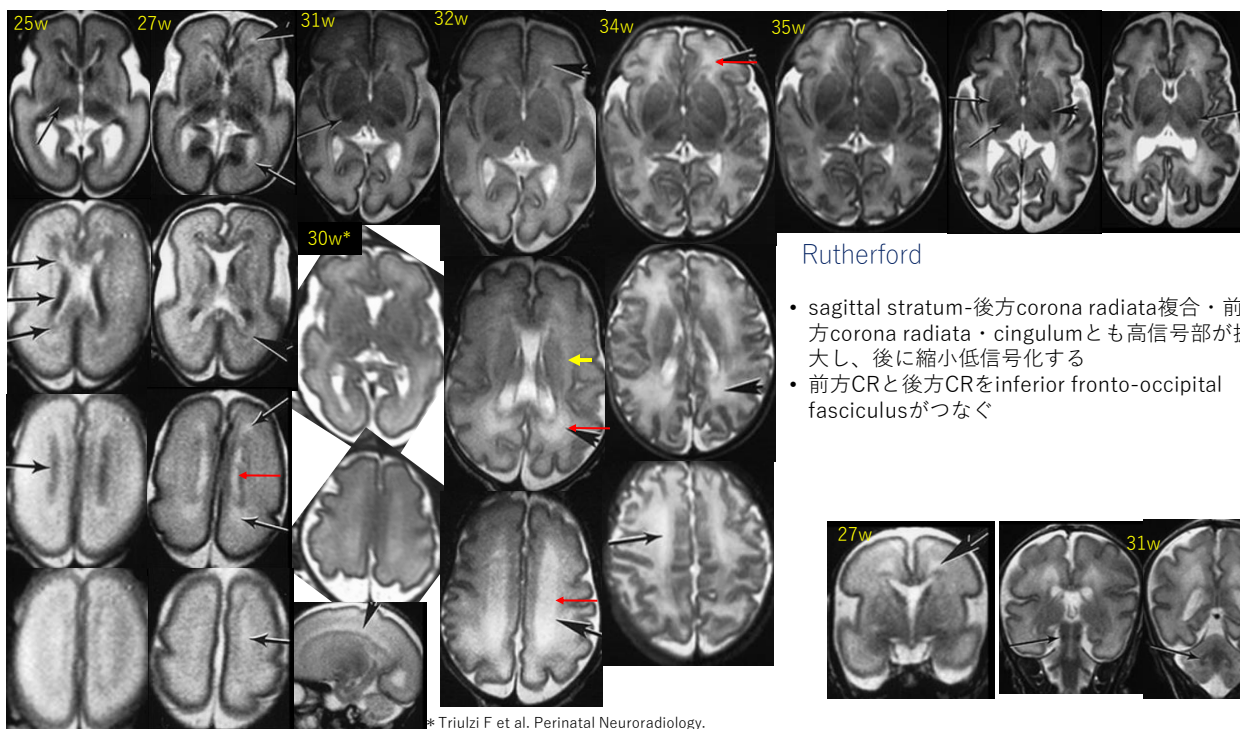
18



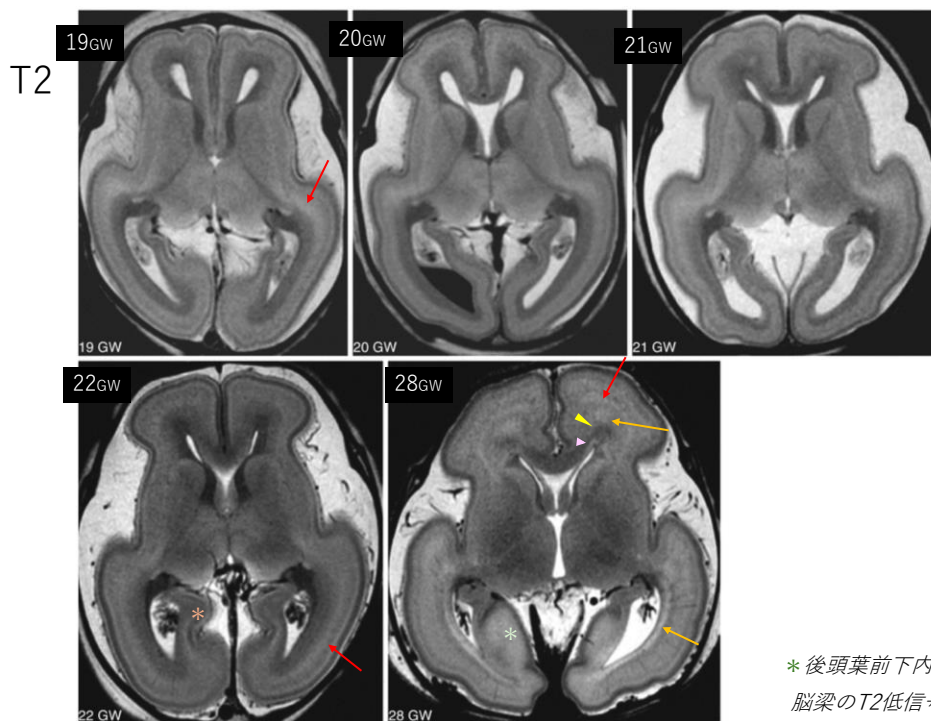
T2高信号部

- cgc **cingulum** は前後走行線維 *ccは上下・左右走行線維
- ptr:ss+cc/ex/Cl+acrは連続する前後走行線維
sagittal stratum-後方corona radiata複合
- acrは前後走行線維 *同部に脳梁線維あり 前方corona radiata
- scrは上下前後走行線維 上方corona radiata





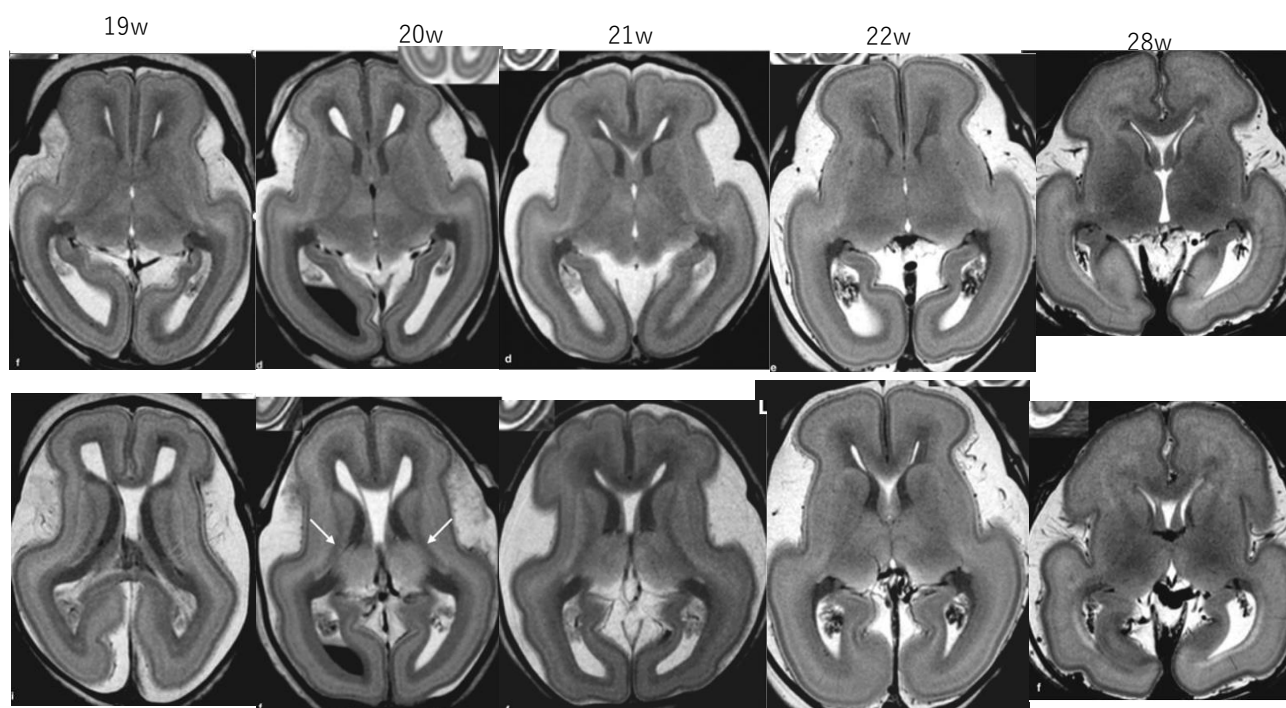
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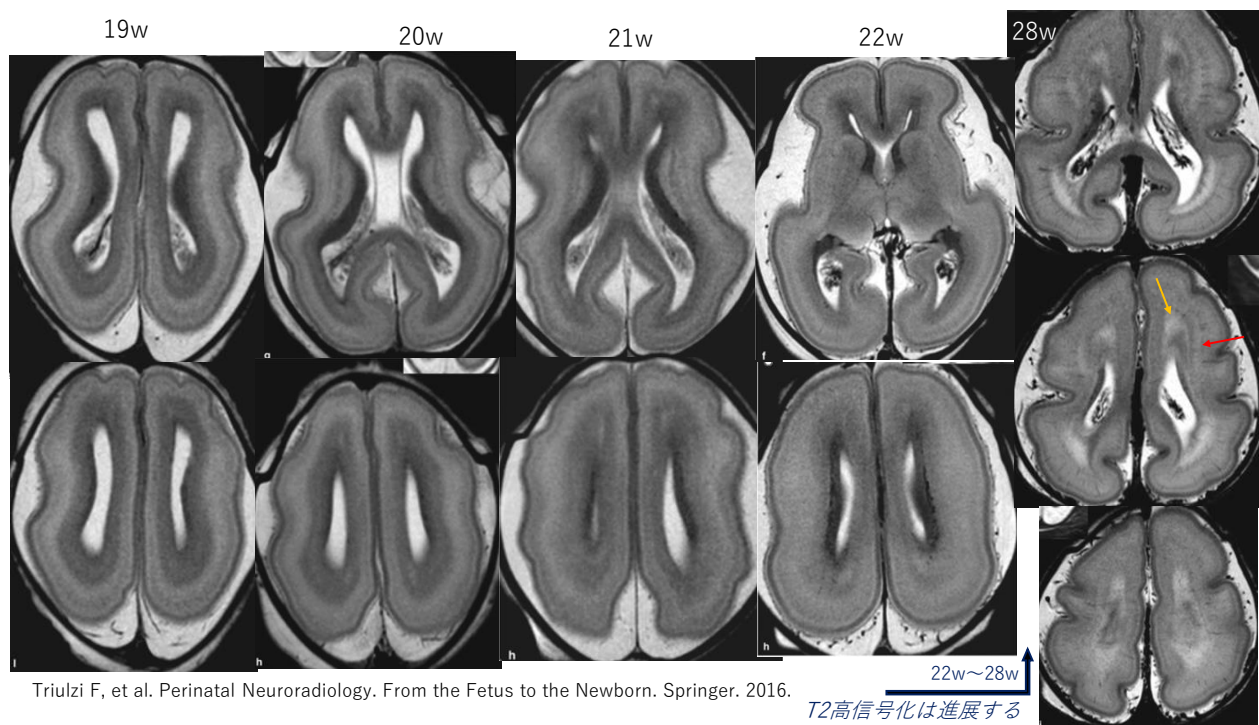
Triulzi F, et al. Perinatal Neuroradiology. From the Fetus to the Newborn. Springer. 2016.

* 後頭葉前下内側は早期分化脳回
脳梁のT2低信号は細胞密度が高い

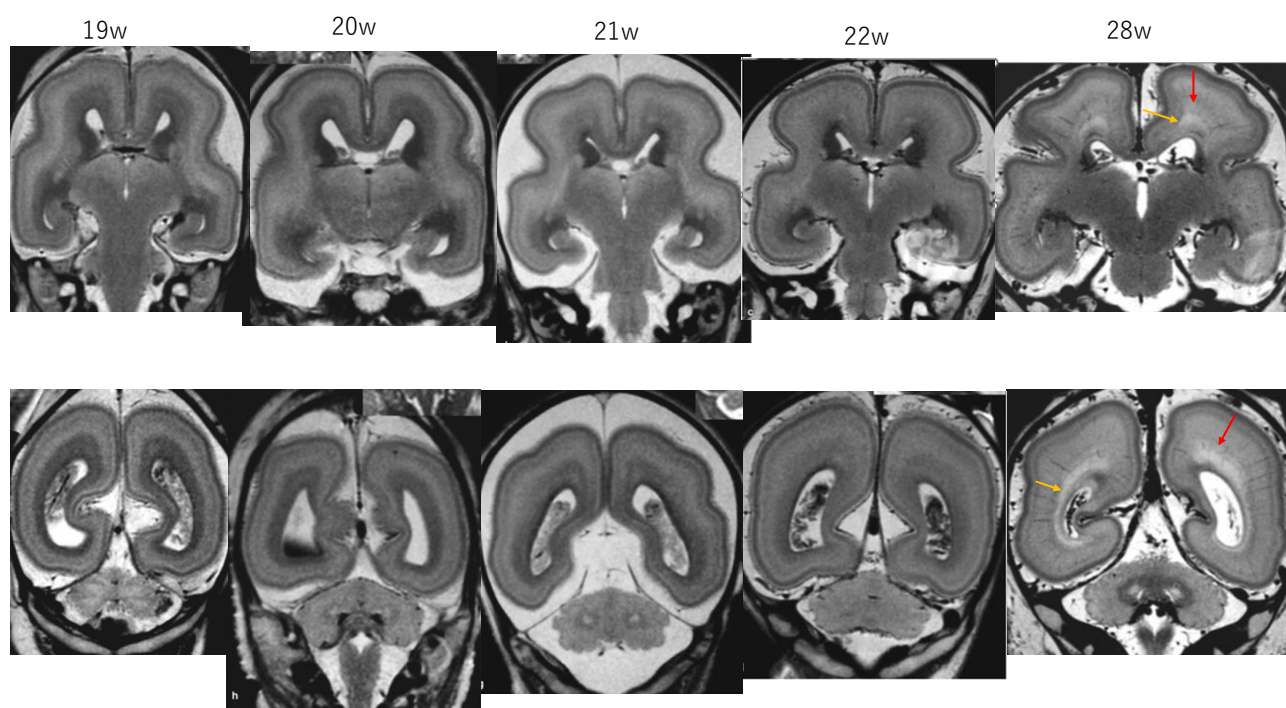
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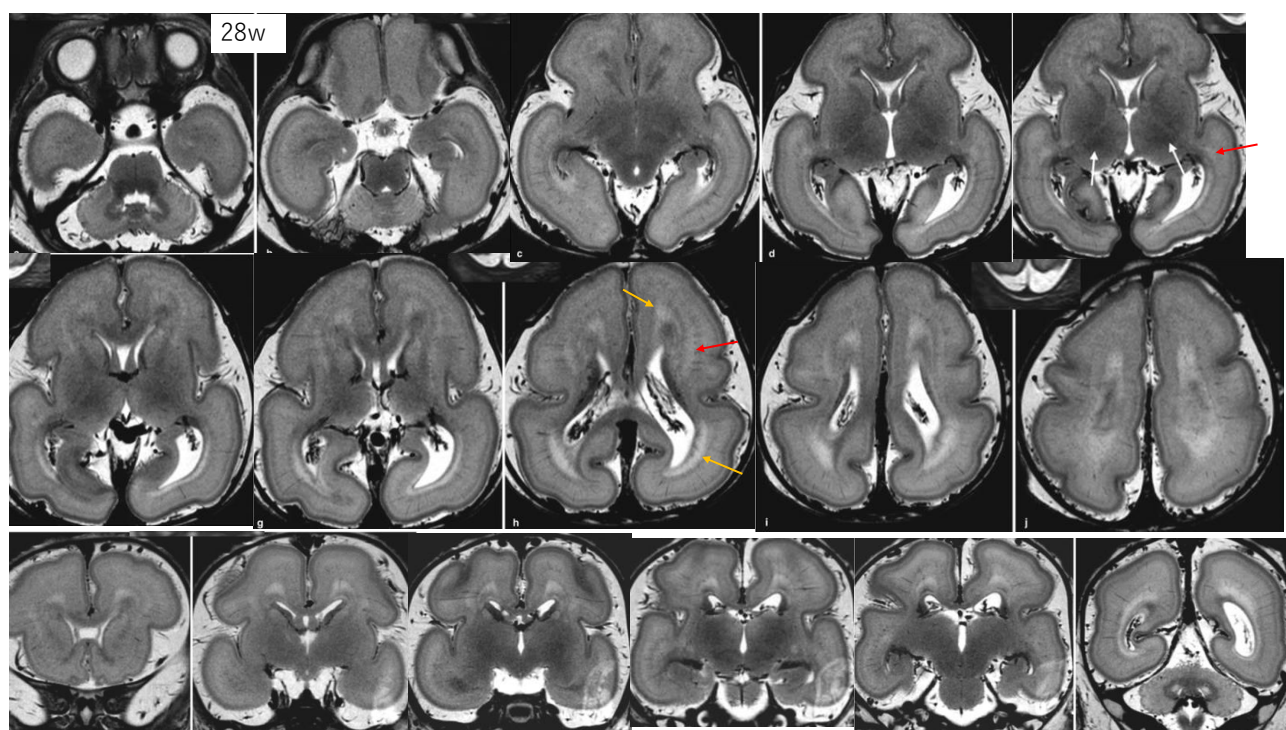
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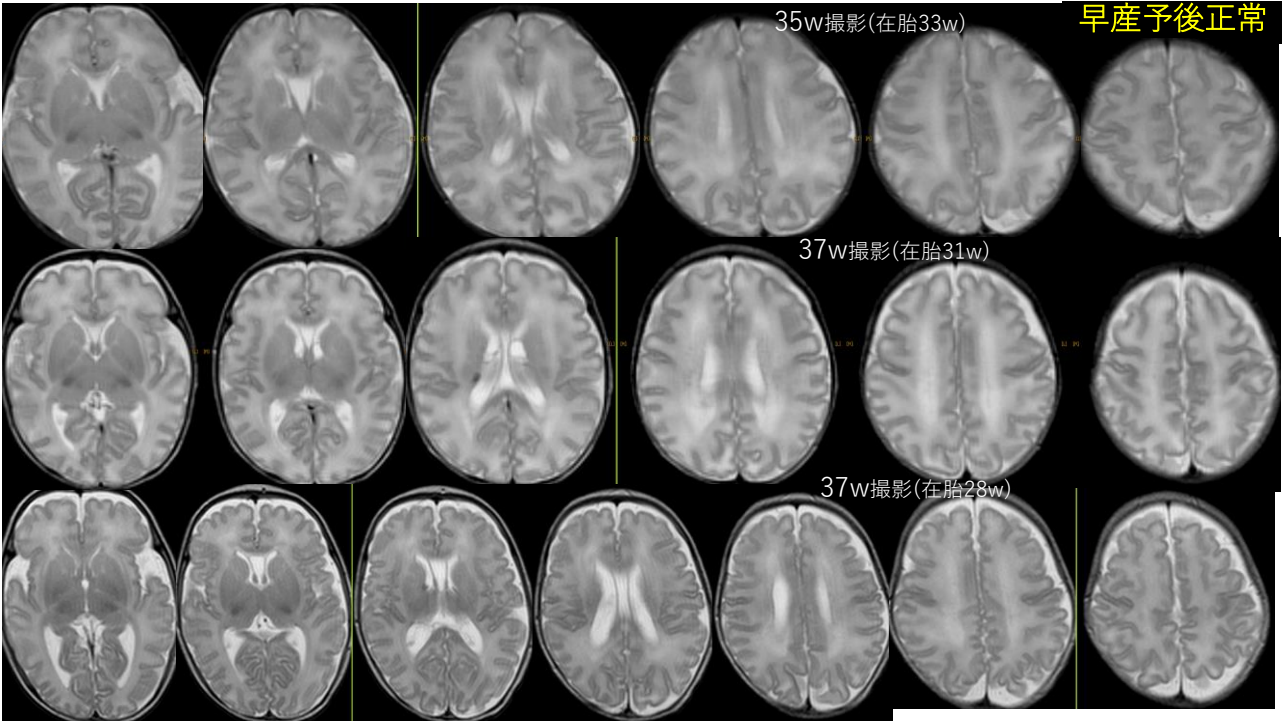
24



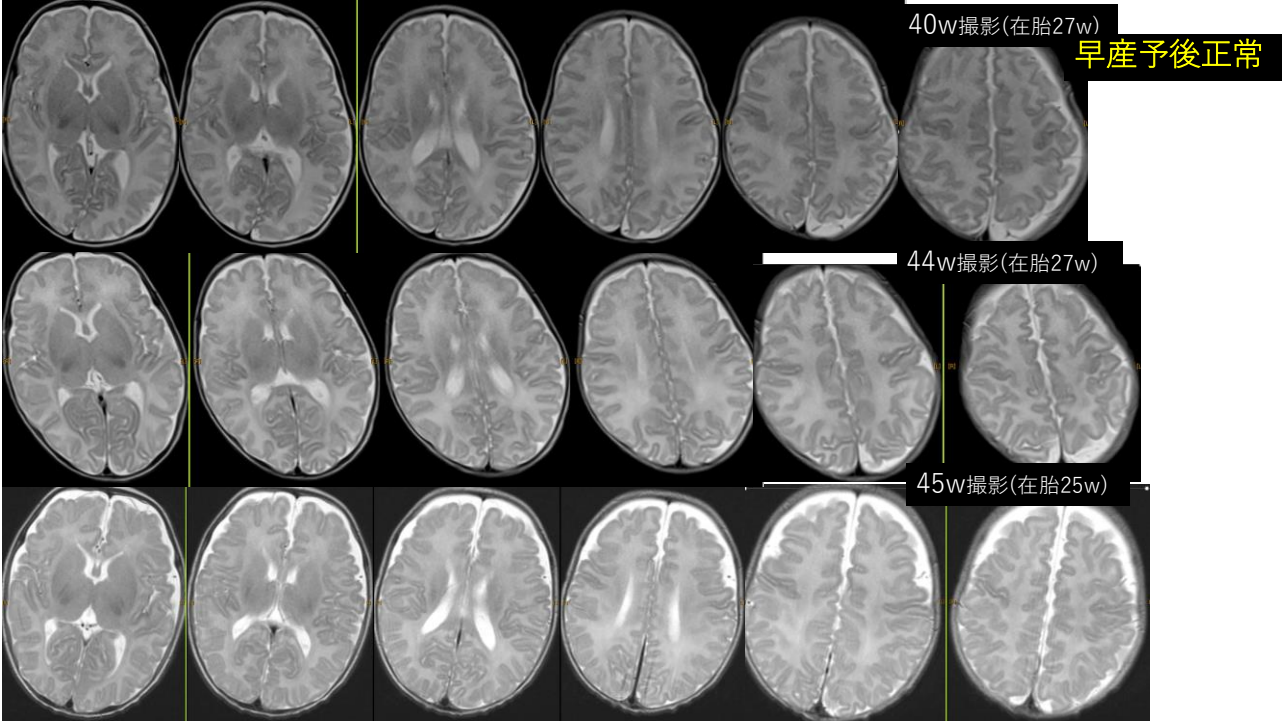
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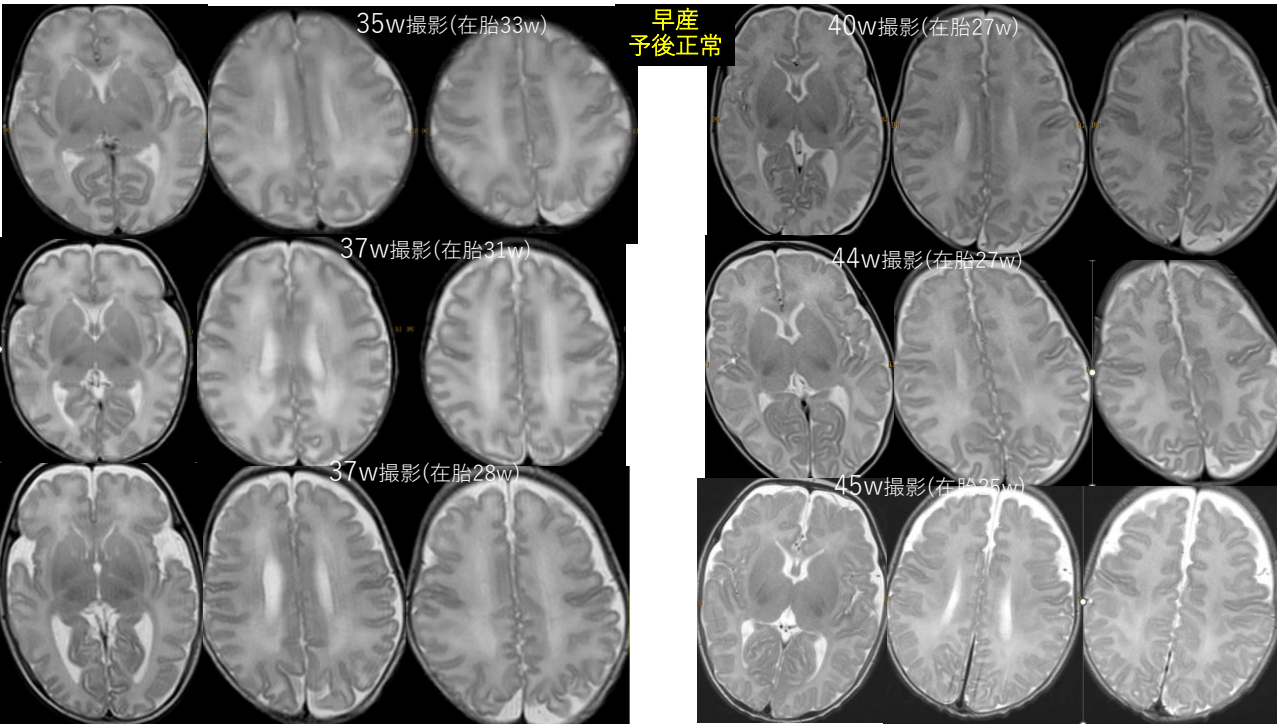
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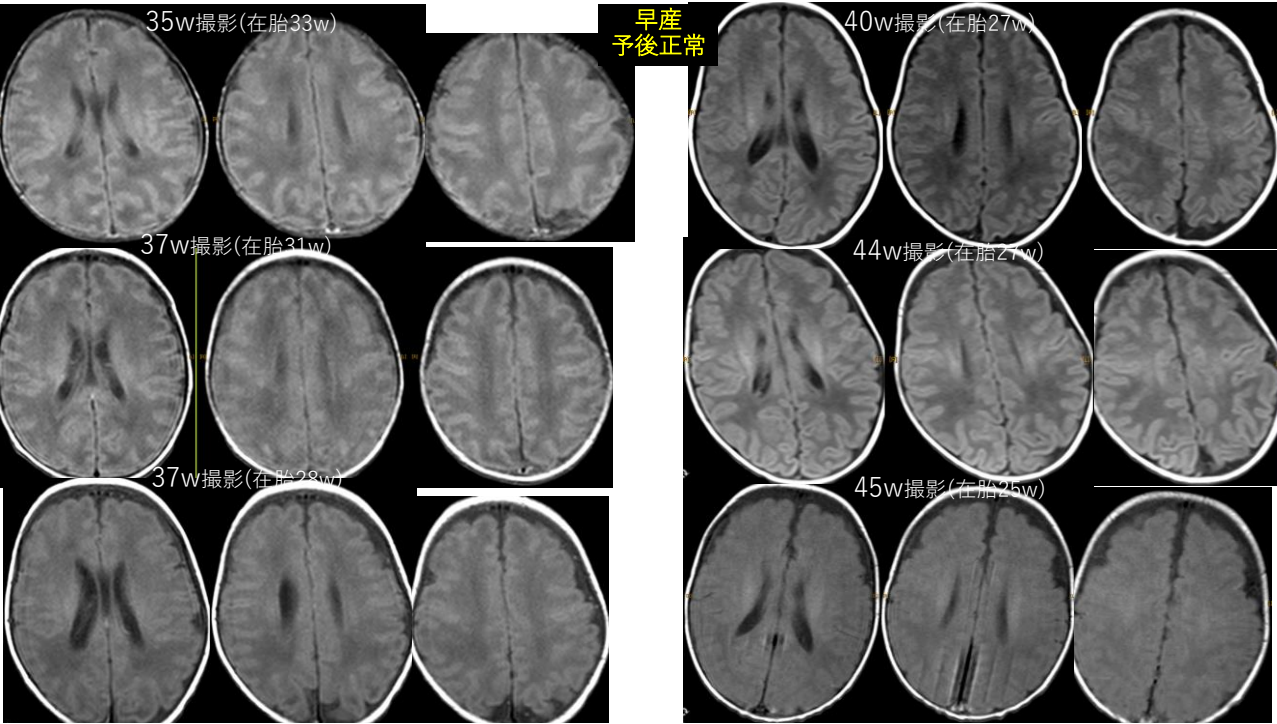
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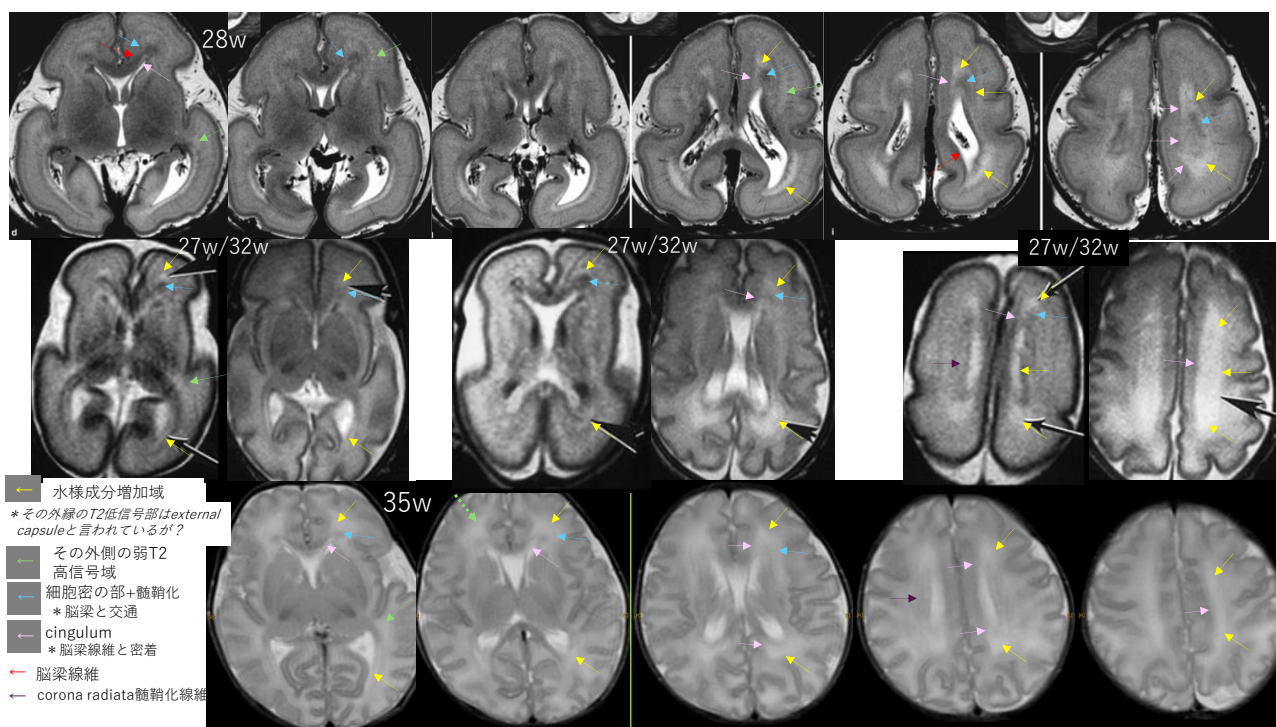
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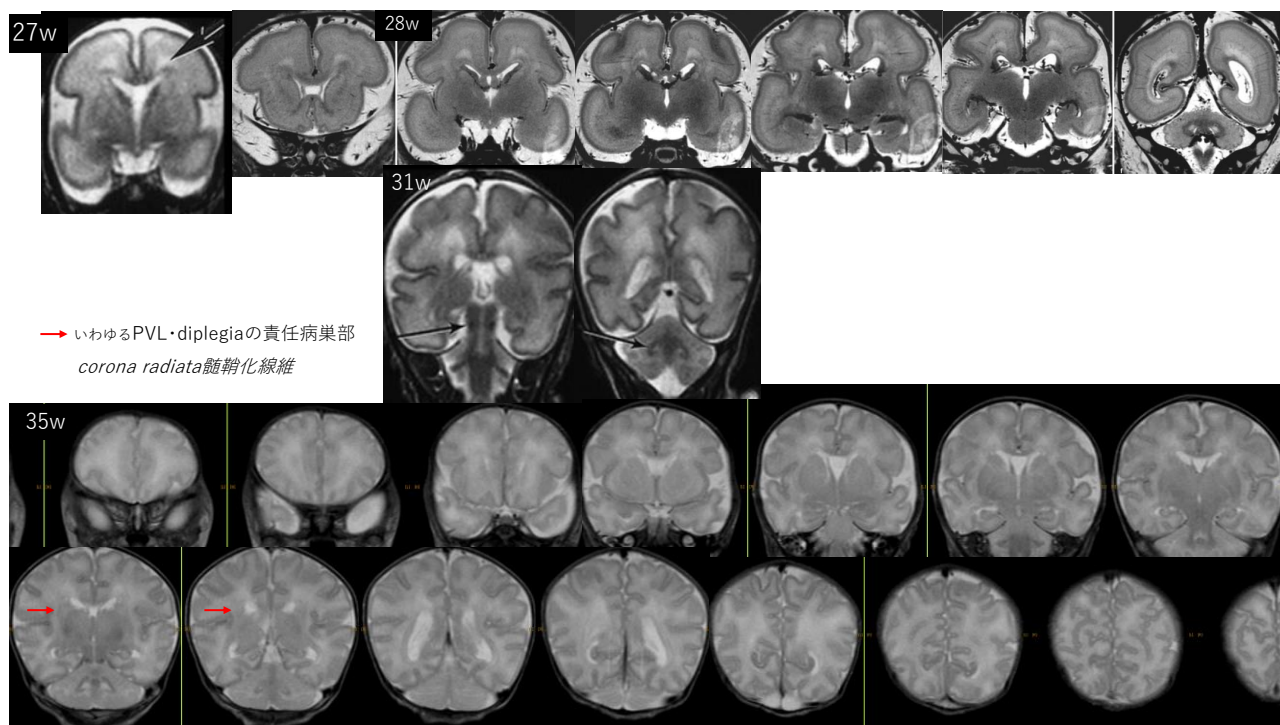
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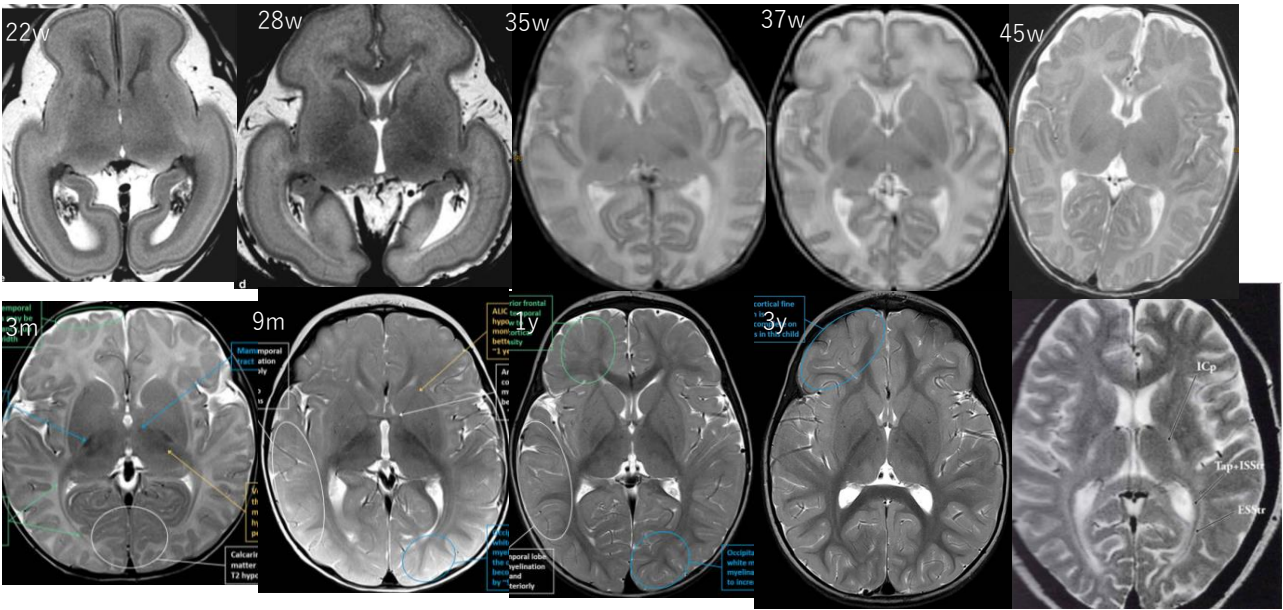
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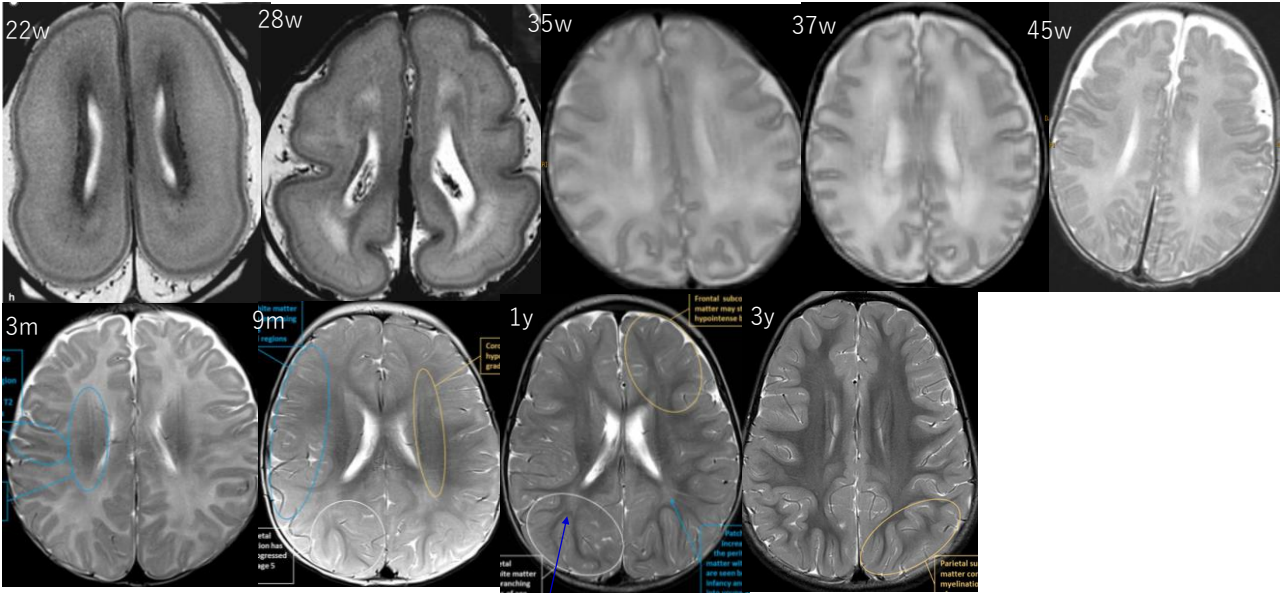
31



32

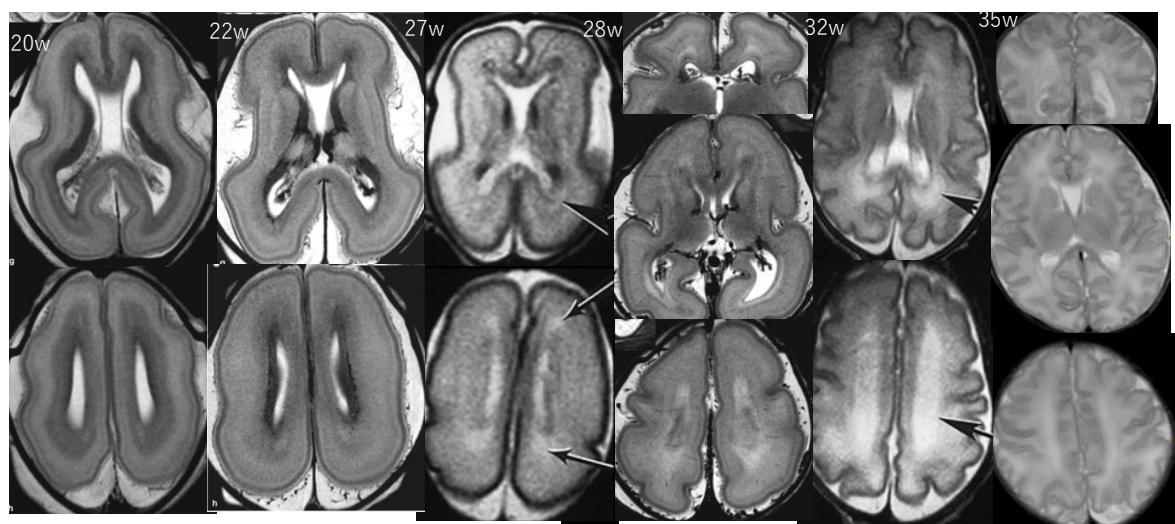


33



terminal zone

34



corona radiata・cingulum complex (CR・Cn複合)

- cingulum [Cn]
- sagittal stratum-後方corona radiata複合 [後方CR]
- 前方corona radiata [前方CR]
- 上方corona radiata [上方CR] ⇨ 錐体路

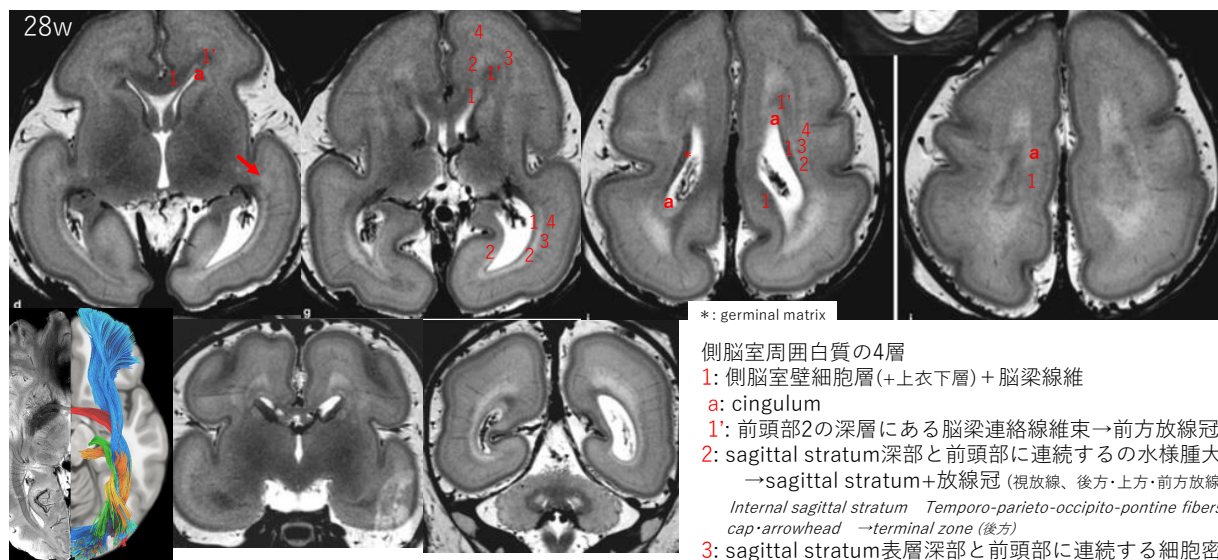
T2高信号部の外縁T2低信号部 (external capsule)の外側弱T2高信号域も含む

32wの障害⇒ 上方CR 後方CR>前方CR Cn

28wの障害⇒ 上方CR>後方CR・前方CR Cn

22wの障害⇒ CR外側部が主

35



*: germinal matrix

側脳室周囲白質の4層

1: 側脳室壁細胞層(+上衣下層) + 脳梁線維

a: cingulum

1': 前頭部2の深層にある脳梁連絡線維束→前方放線冠

2: sagittal stratum深部と前頭部に連続するの水様腫大部

→sagittal stratum+放線冠 (視放線、後方・上方・前方放線冠)

Internal sagittal stratum Temporo-parieto-occipito-pontine fibers, ILF cap・arrowhead →terminal zone (後方)

3: sagittal stratum表層深部と前頭部に連続する細胞密部

≠ External capsule

4: sagittal stratum表層浅部と前頭部に連続する細胞疎部

3+4は同一実体

→sagittal stratum+放線冠 (視放線、後方・上方・前方放線冠)

External sagittal stratum Optic radiation, IFOF

黄: Posterior thalamic peduncle (optic radiationを含む)

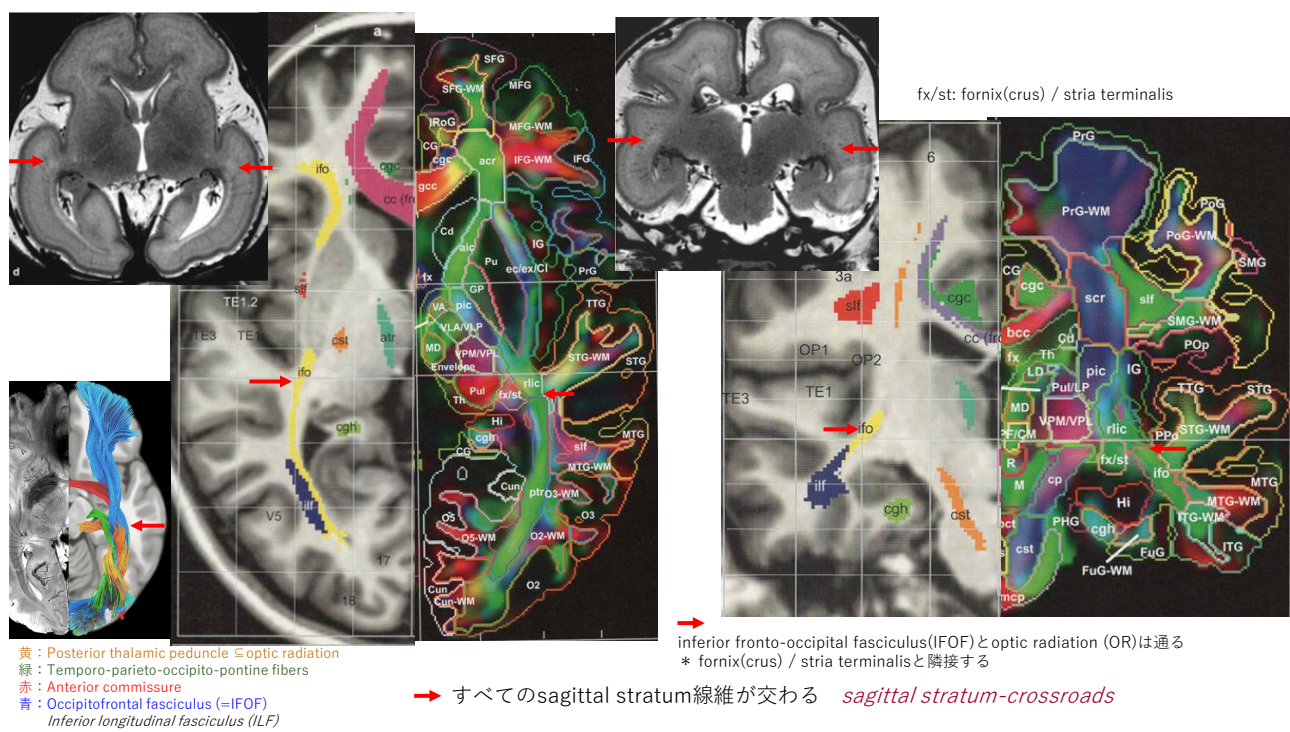
緑: Temporo-parieto-occipito-pontine fibers

赤: Anterior commissure

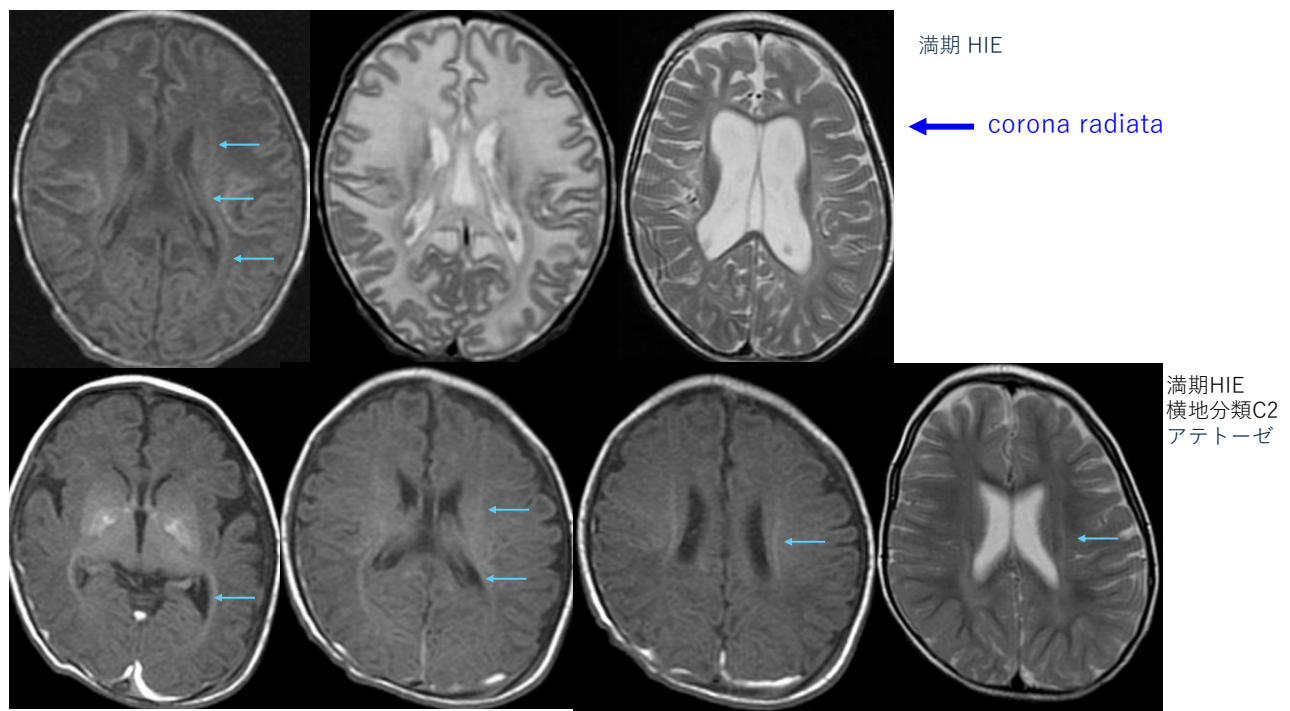
青: Occipitofrontal fasciculus =inferior fronto-occipital fasciculus(IFOF)

Inferior longitudinal fasciculus (ILF)

36



37



38