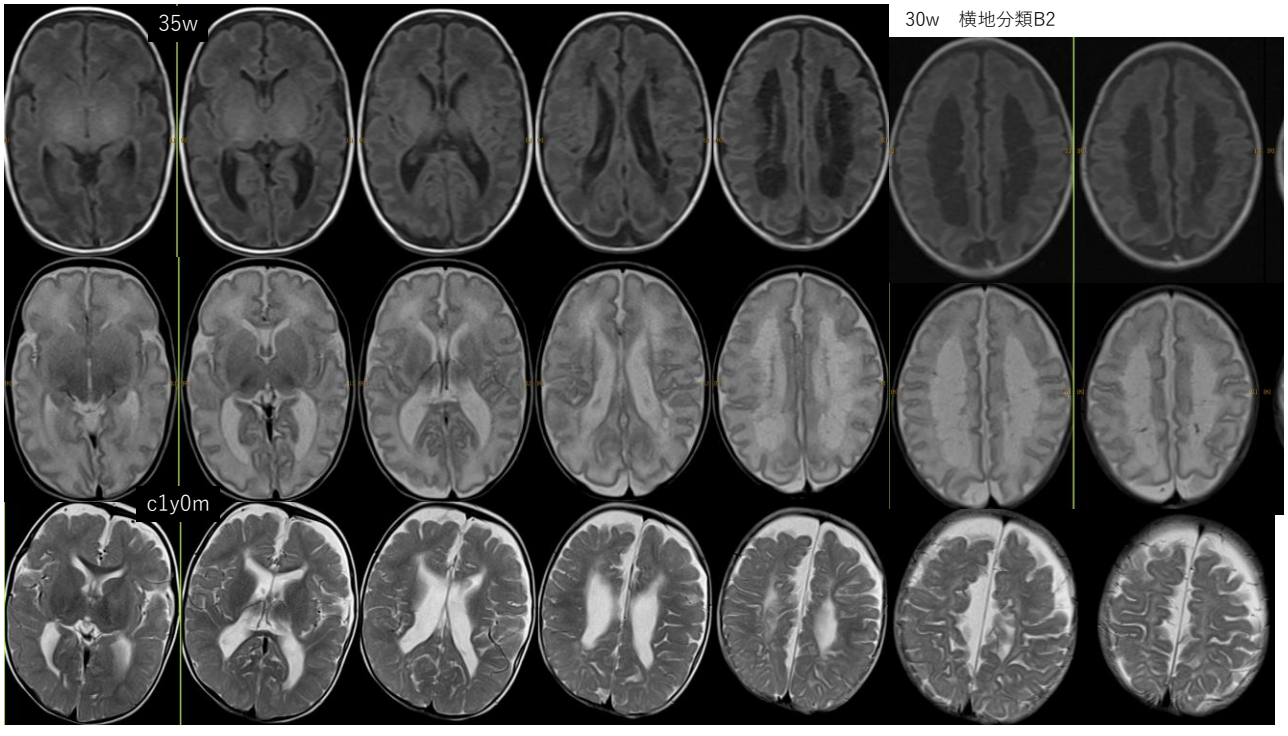
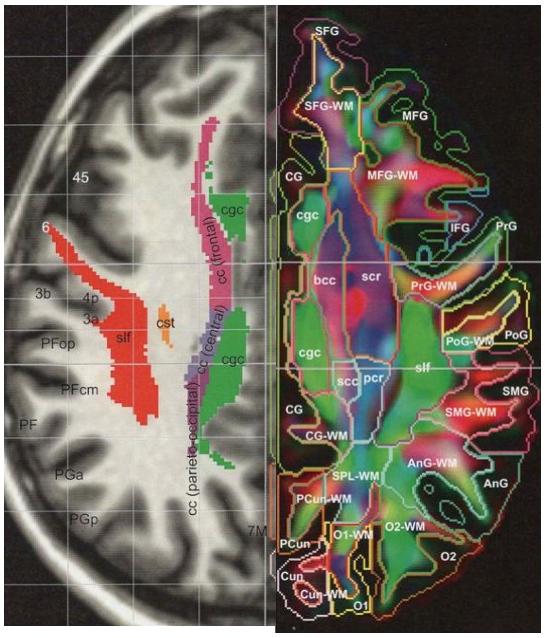

胎児期白質分化
crossroads
corona radiata
corpus callosum
横地健治

1

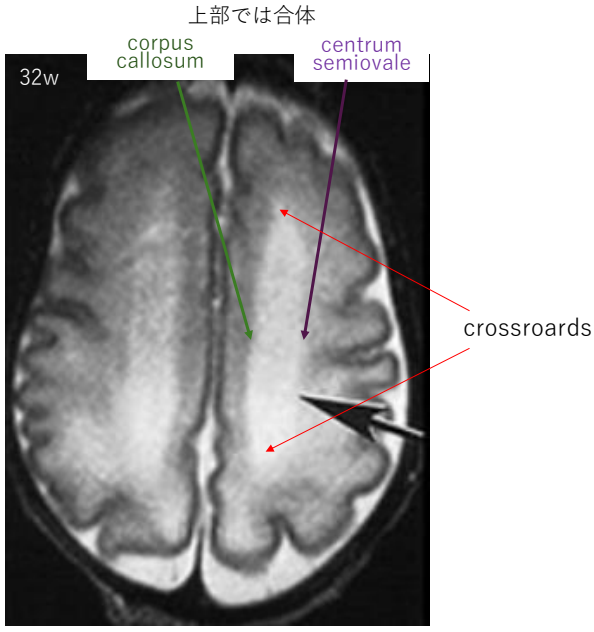

35w
30w　横地分類B2
c1y0m

2



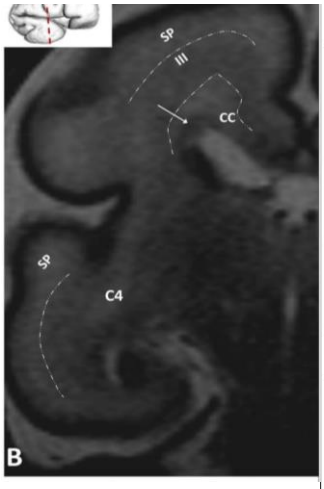
cc: corpus callosum　　cr: corona radiata

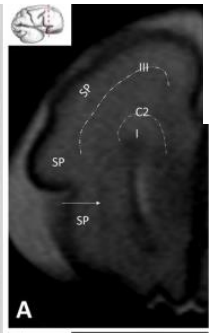
脳梁と放線冠は一体化

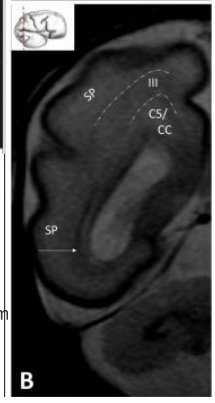


Rutherford: **MRI of the Neonatal Brain**

3





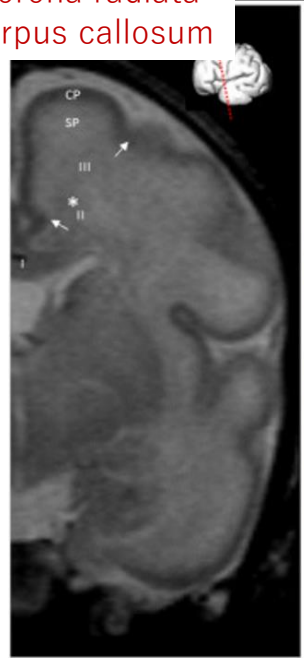


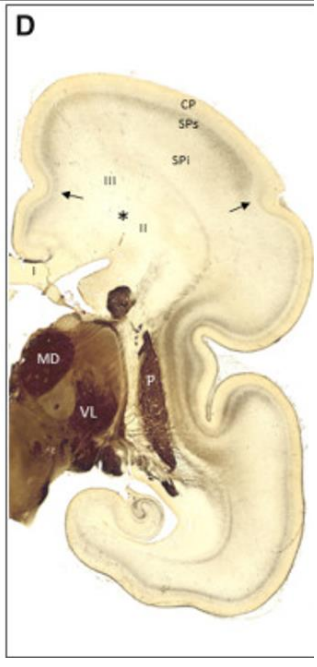
28wでsegment IIIがある

Katušić A, et al. Transient structural MRI patterns correlate with the motor functions in preterm infants. Brain & Development, 2020.363-371.

crossroads
corona radiata
corpus callosum

28-31WG(26-29PCW)





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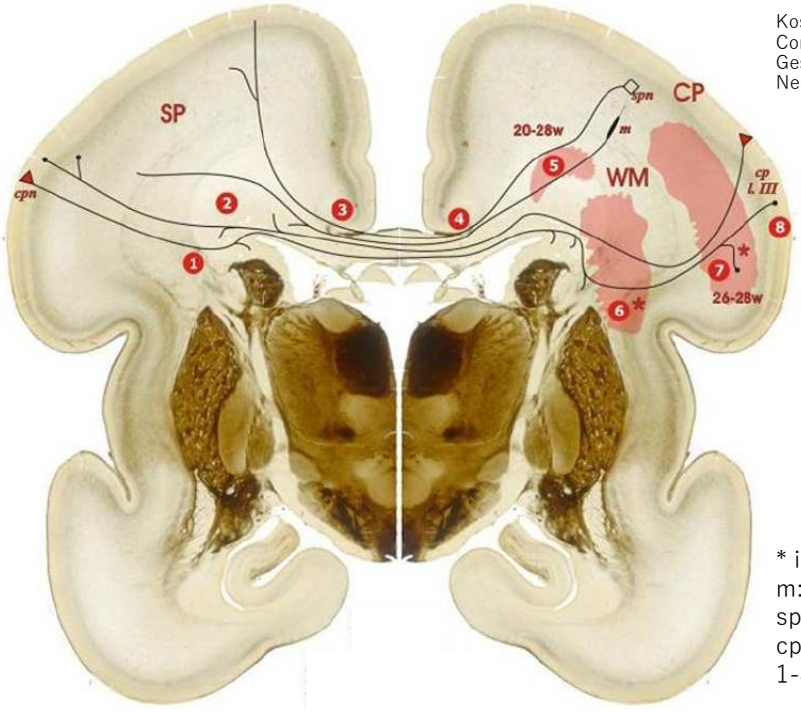


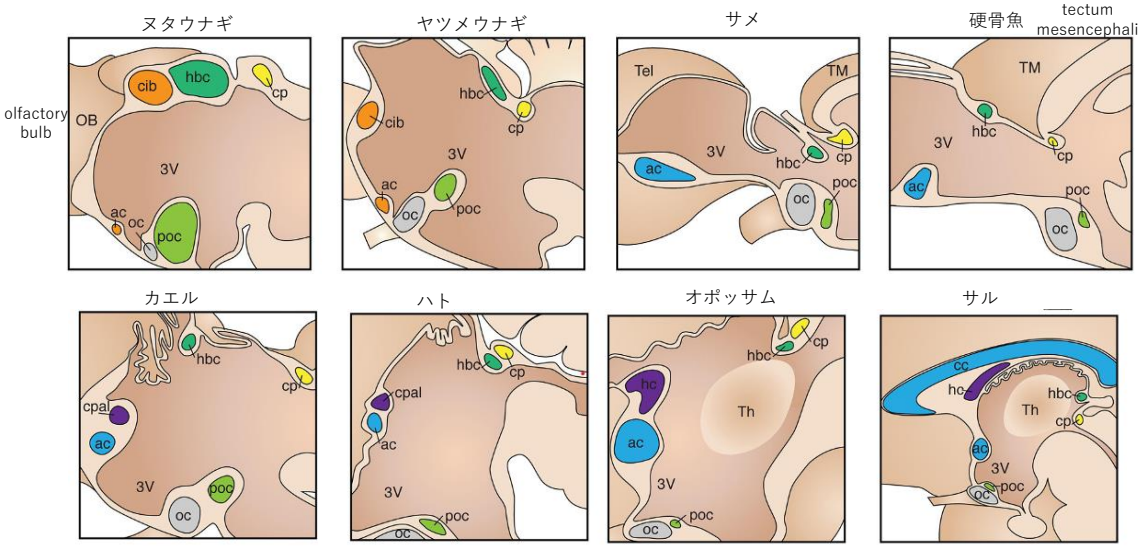
Kostović I, et al. Fundamentals of the Development of Connectivity in the Human Fetal Brain in Late Gestation: From 24 Weeks Gestational Age to Term. J Neuropathol Exp Neurol 2021;80:393-414.

胎児期の脳梁線維交通の相方は
subplate neuron

* intermingling with thalamocortical
m: migrating neuron
spn: subplate neuron
cpn: cortical palate neuron
1-8: guidance zones and decision points

5

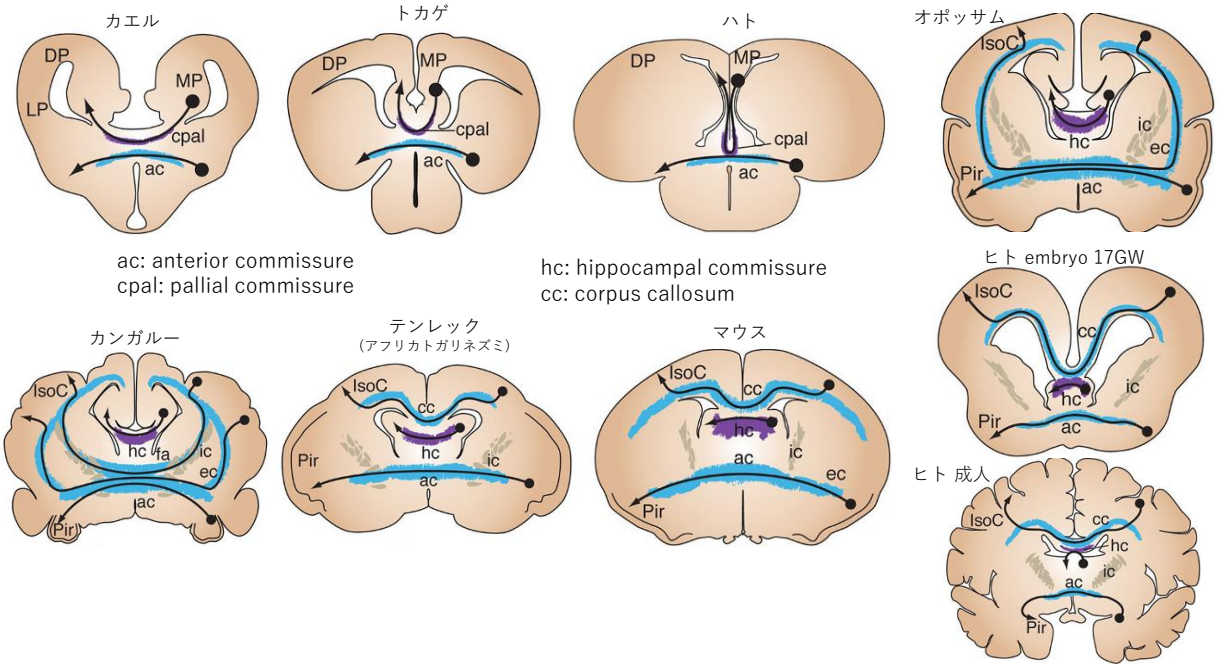
Suárez R, et al. Evolution and development of interhemispheric connections in the vertebrate forebrain. Front Hum Neurosci 2014:8:497.



cib: commissure interbulbaris
ac: anterior commissure
cpal: pallial commissure
hbc: habenular commissure
oc: optic chiasm
poc: post-optic commissure
cp: posterior commissure
hc: hippocampal commissure
cc: corpus callosum

6

DP: dorsal pallium　MP: medial pallium　LP: lateral pallium　Iso: isocortex　Pir: pyriform cortex
ec: external capsule　ic: internal capsule　fa: fasciculum aberrans



7

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)

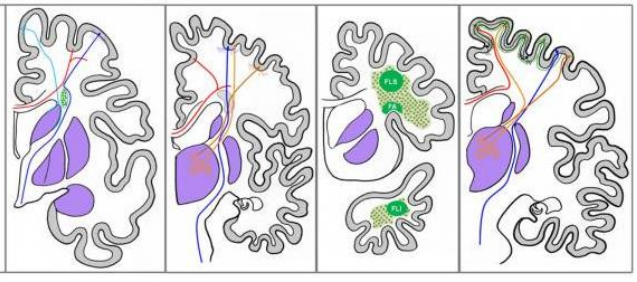
Intermediate compartment
- Crossroads of projection pathways – (segment II) IIa
  - – Thalamocortical fibers
  - – Cortico-fugal fibers
  - – Callosal radiation
  - – Associative sagittal fibers
- Sagittal axonal strata – (segment II)IIb
  - – Thalamocortical pathways
  - – Basal forebrain cholinergic 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)

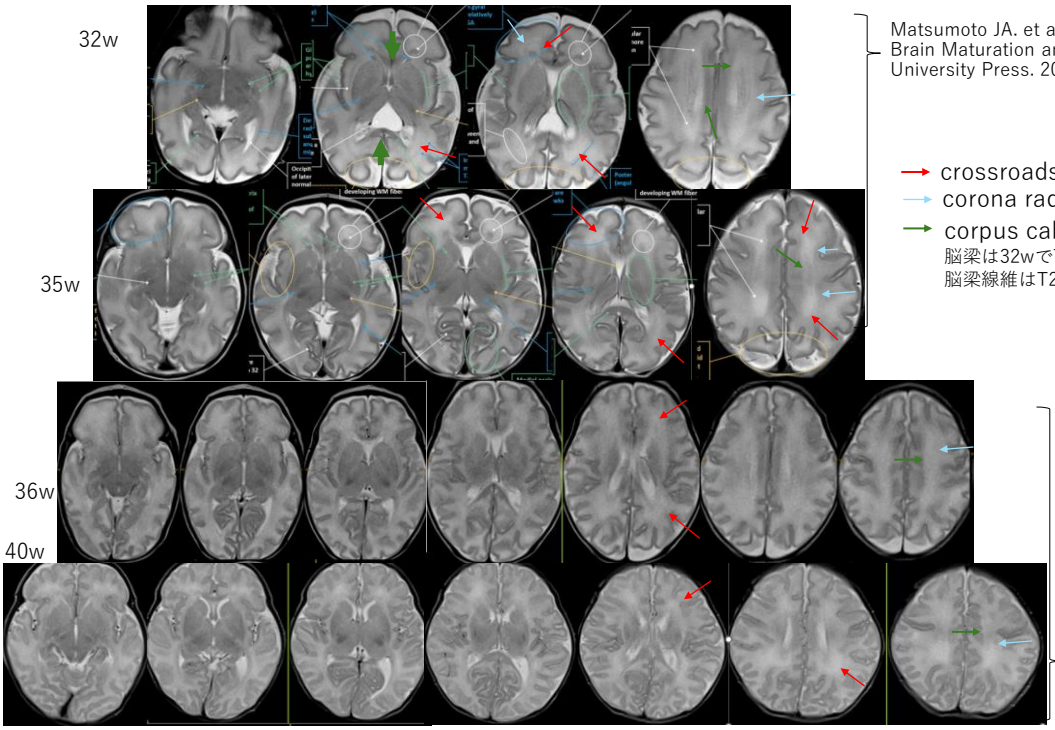
大脳白質の発達的区分

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

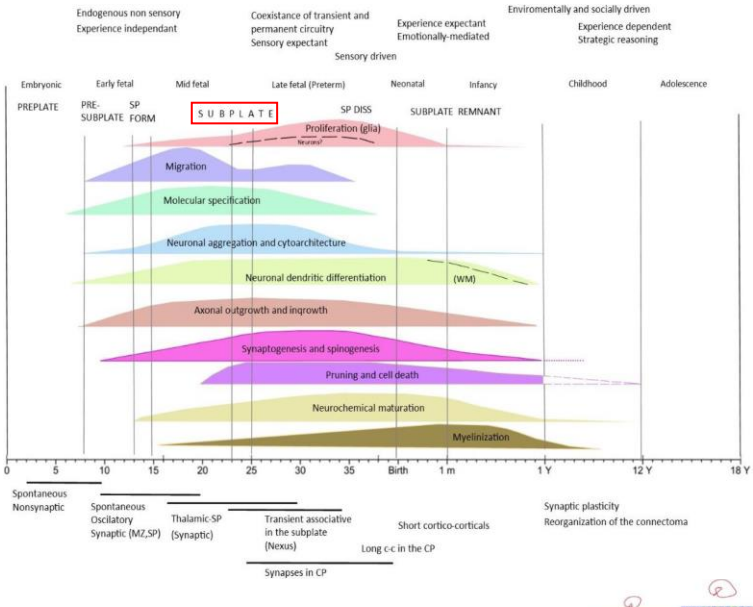
Von Monakowのsegment　Crossroads　Sagittal strata　Subplate

	Deep periventricular	Intermediate		Distal (superficial)
Compartments (where?)	Segment I (periventricular pathway)	Segment II (crossroads and sagital 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 cortiocopontine)	Sensory (thalamocortical) Motor (pyramidal)	Long associative (FLS, FA, FLI, etc.) Sensory	Short cortico-cortical (U fibers) Intracortical
Schematic representation of pathways (connectivity)				

8



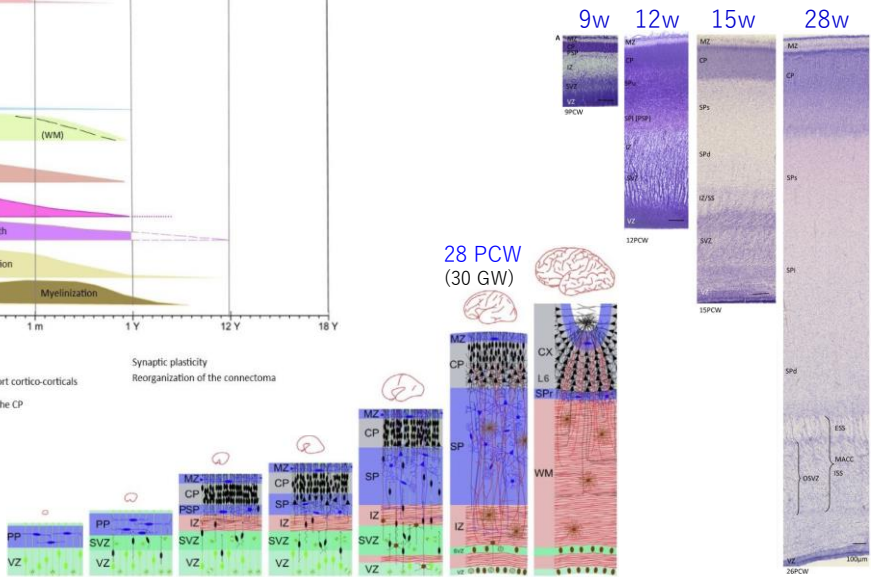
9



Kostović I et al. Sublaminar organization of the human subplate: developmental changes in the distribution of neurons, glia, growing axons and extracellular matrix. J Anat. 2019;235:481-506.

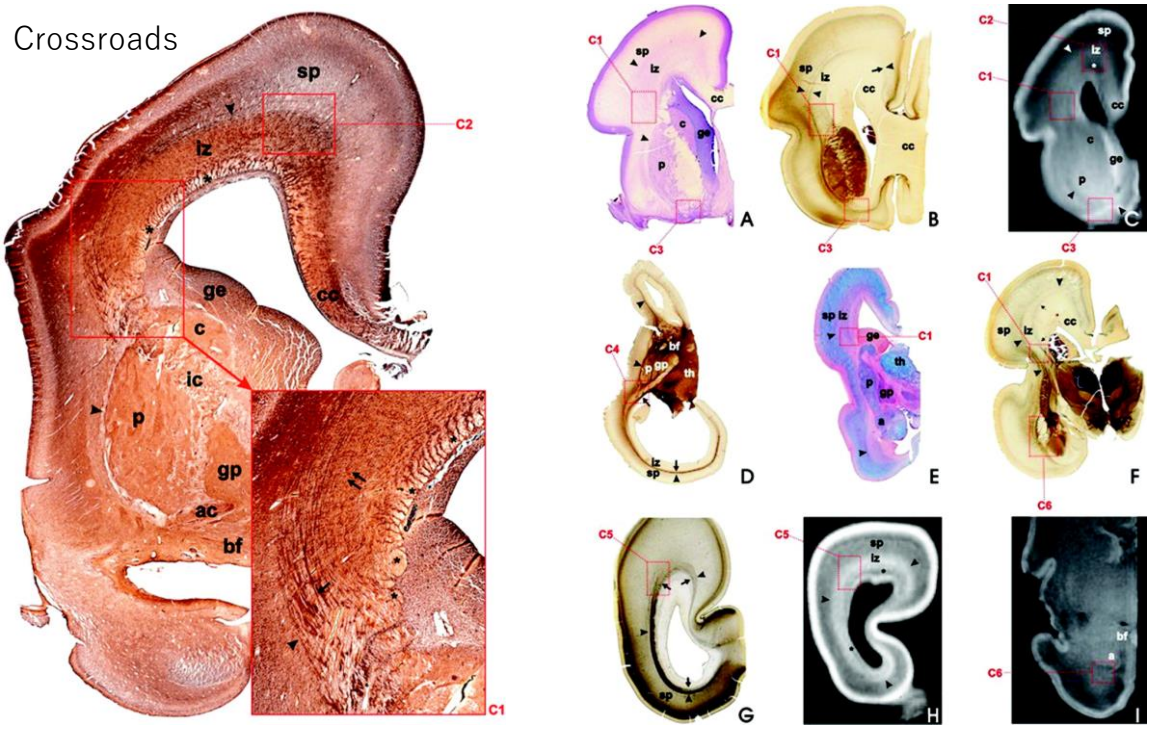
- 34wからsubplateはdissolution消退
- Synapse-rich subplate compartment (SPC)はsubplate remnantとして残る

c-c: cytoarchitectonic compartment



10

Crossroads



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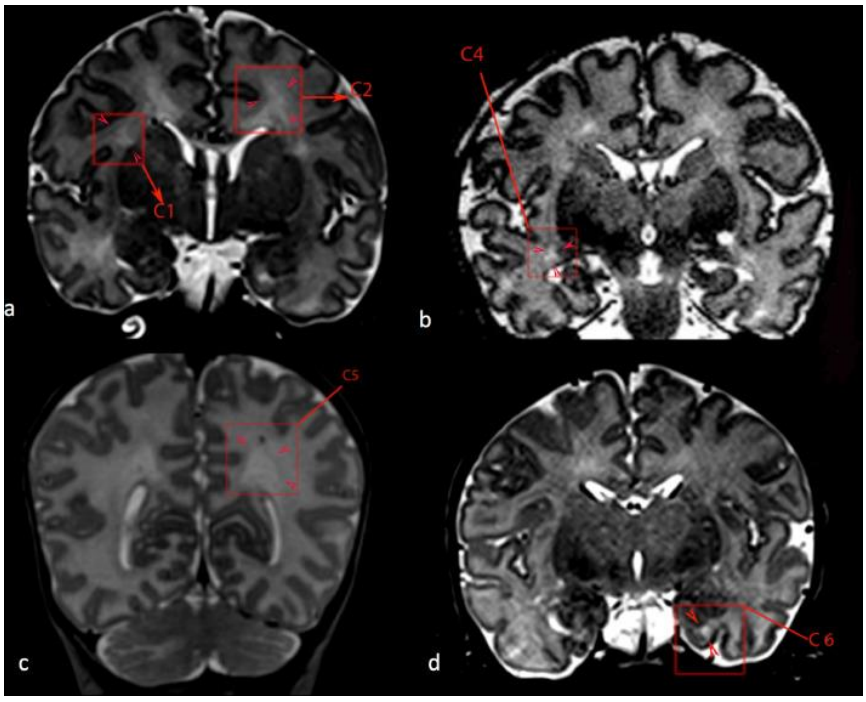
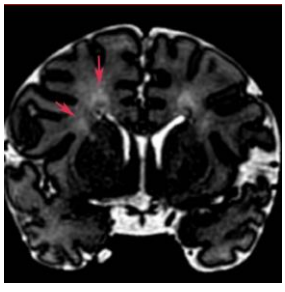


Marie P Pittet, Lana Vasung, Petra S Huppi, Laura Merlini. Newborns and preterm infants at term equivalent age: A semi-quantitative assessment of cerebral maturity. Neuroimage Clin 2019;24:102014.



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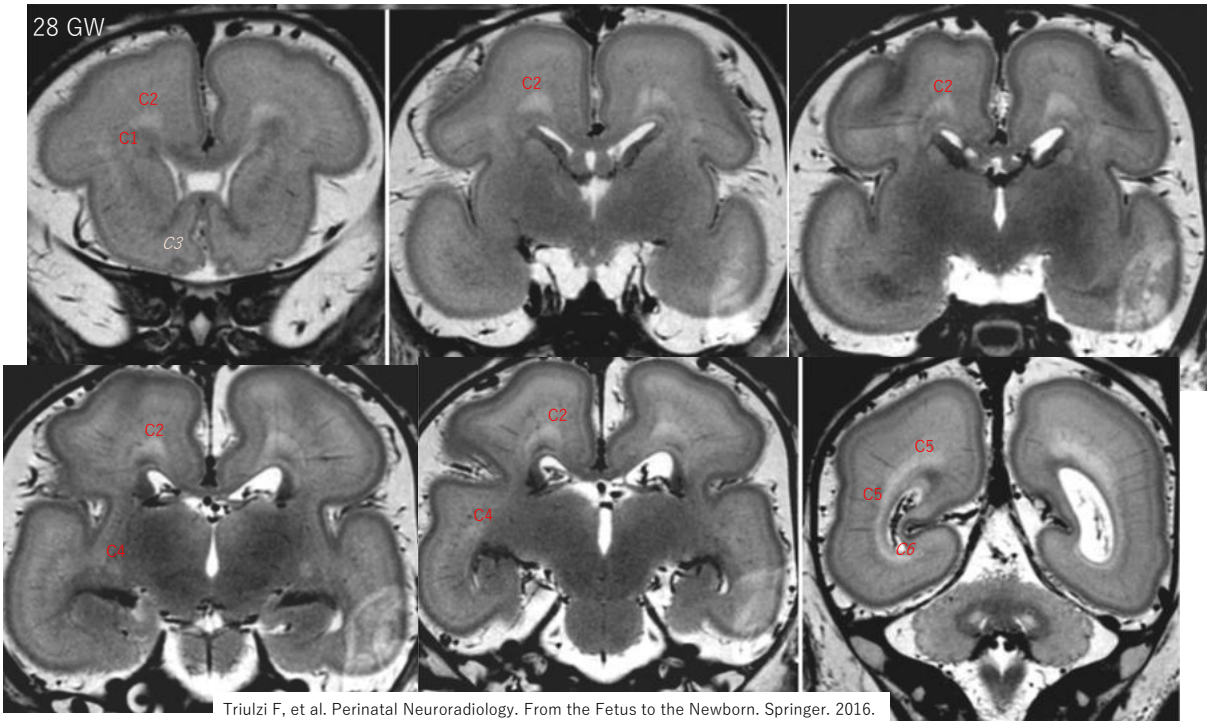
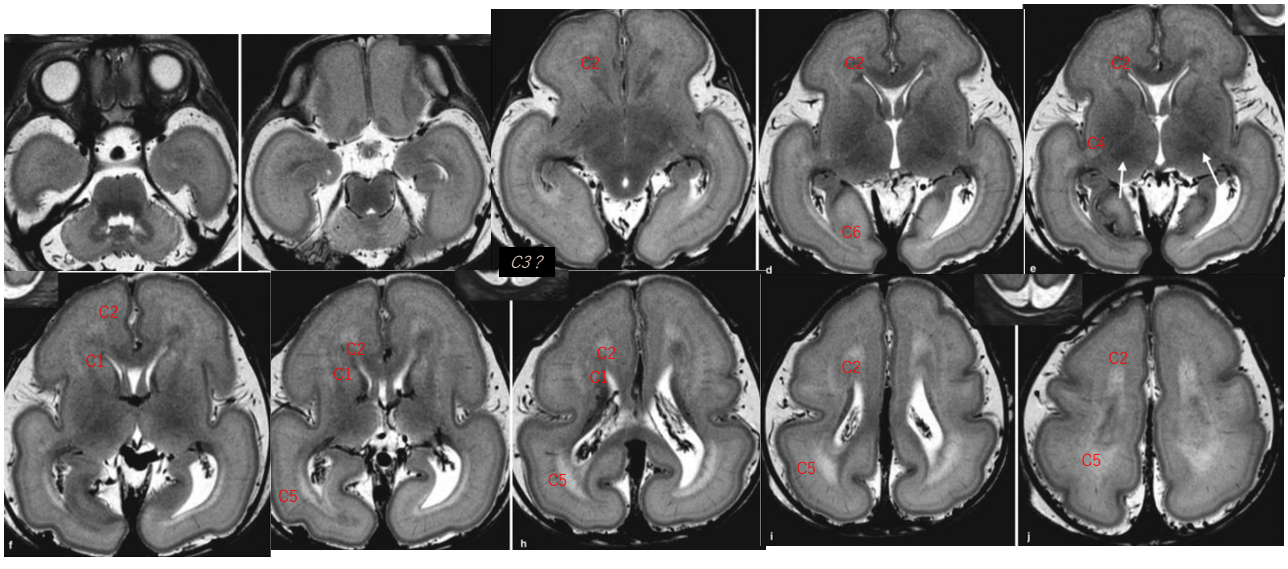


Triulzi F, et al. Perinatal Neuroradiology. From the Fetus to the Newborn. Springer. 2016.

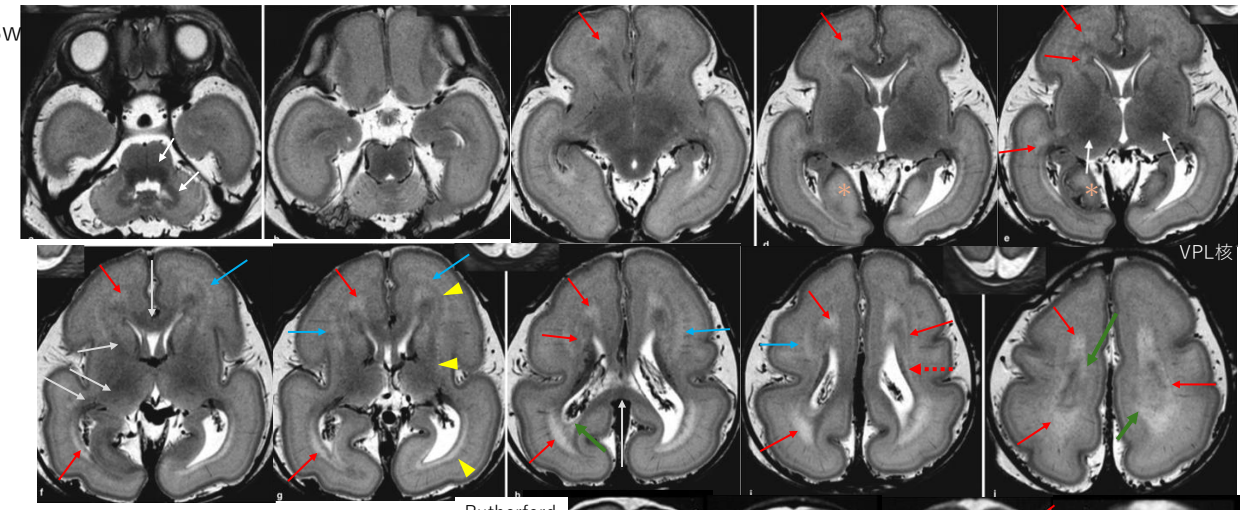
13



CrossroadsのC1-C6の分類は限界がある

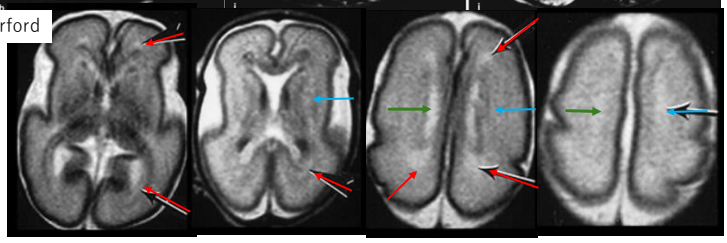
14

28w



Rutherford

27w



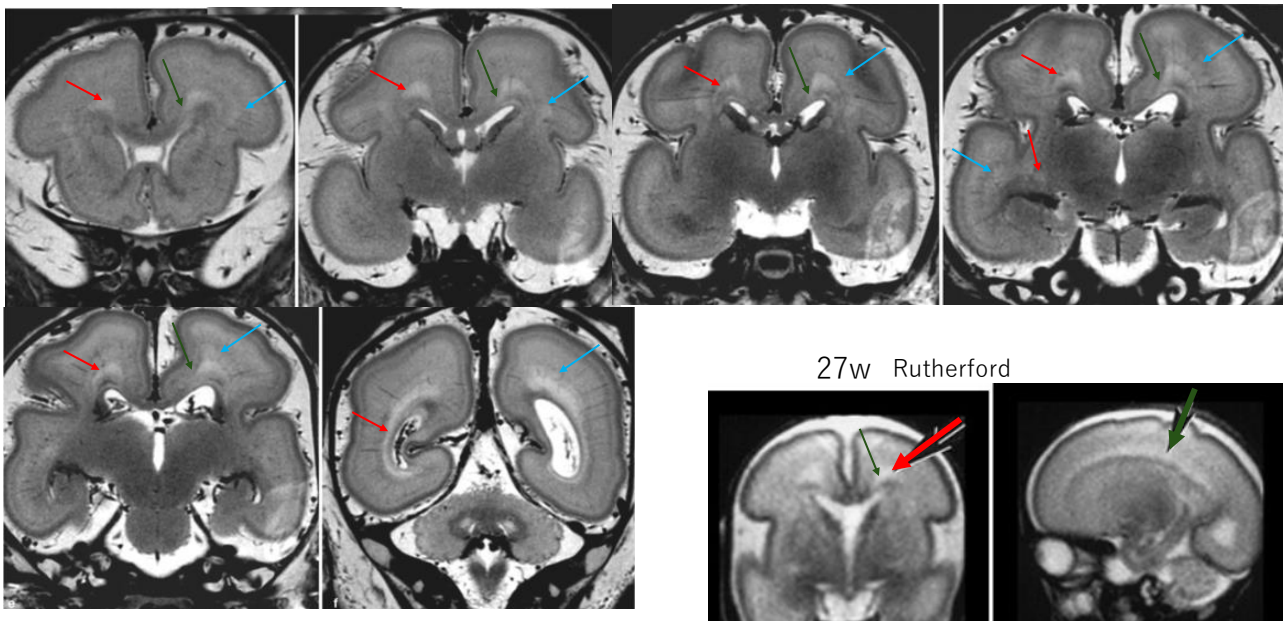
crossroads　corona radiata
external capsule
corpus callosum

＊ 後頭葉前下内側は早期分化脳回

→ 髄鞘化　脳梁・内包はT2低信号

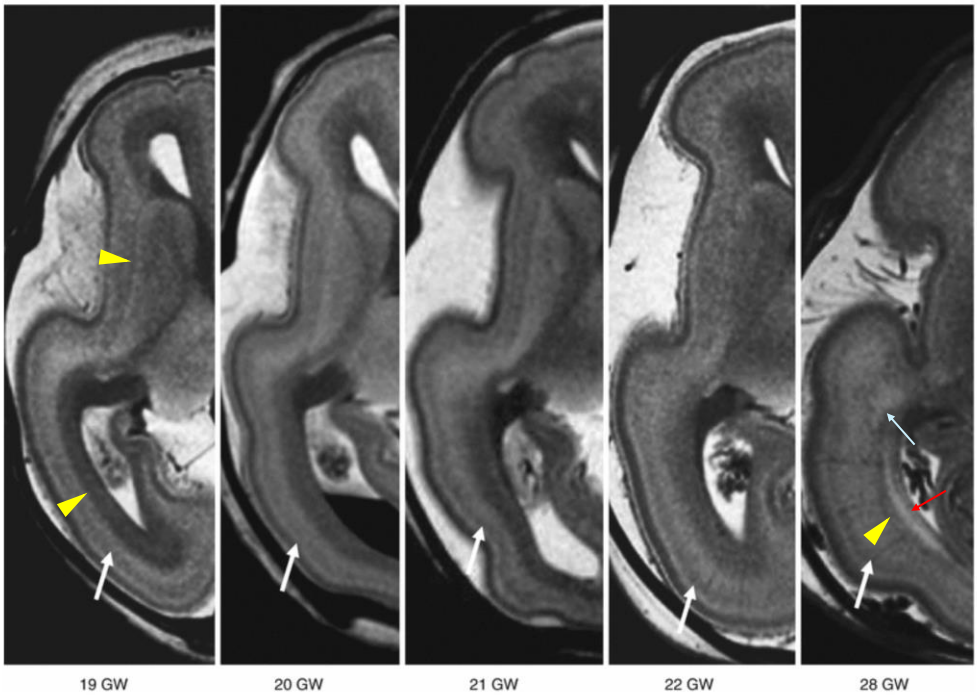
15

28w　Triulzi F



27w　Rutherford

16



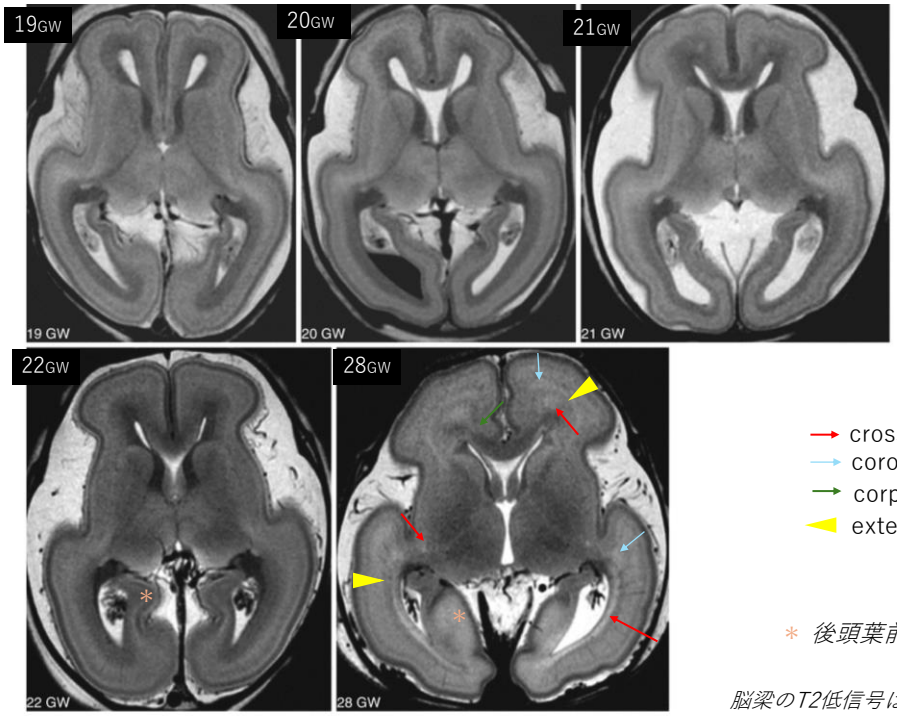
Triulzi F, et al. Perinatal Neuroradiology. From the Fetus to the Newborn. Springer. 2016.

crossroads
corona radiata
corpus callosum
external capsule

矢印はsubplateの表層部にあるthalamocortical axons

17

T2



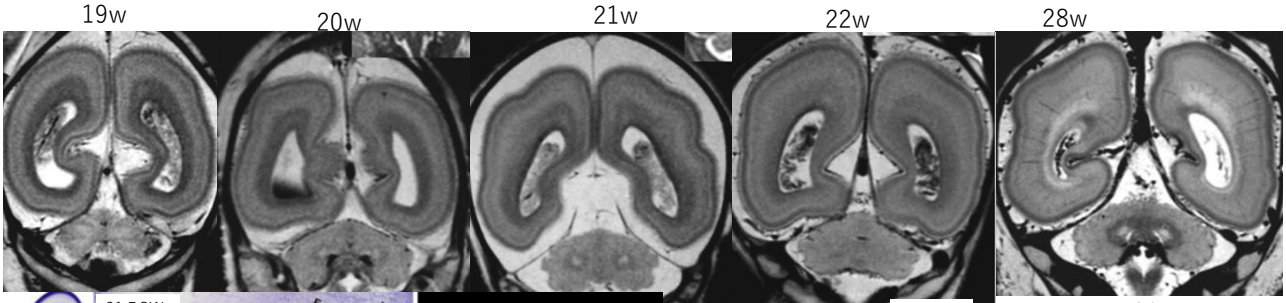
Triulzi F, et al. Perinatal Neuroradiology. From the Fetus to the Newborn. Springer. 2016.

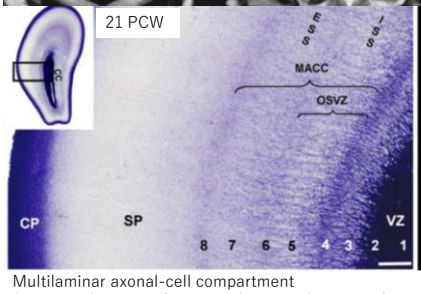
crossroads
corona radiata
corpus callosum
external capsule

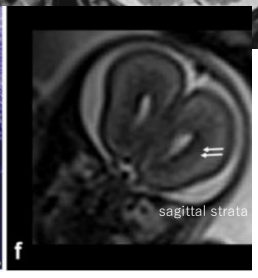
＊ *後頭葉前下内側は早期分化脳回*

脳梁のT2低信号は細胞密度が高い

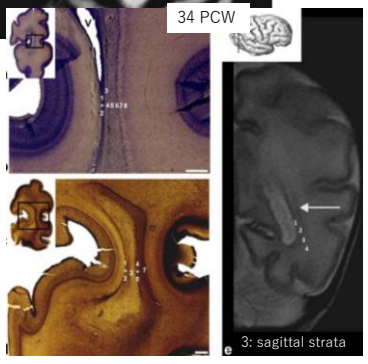
18







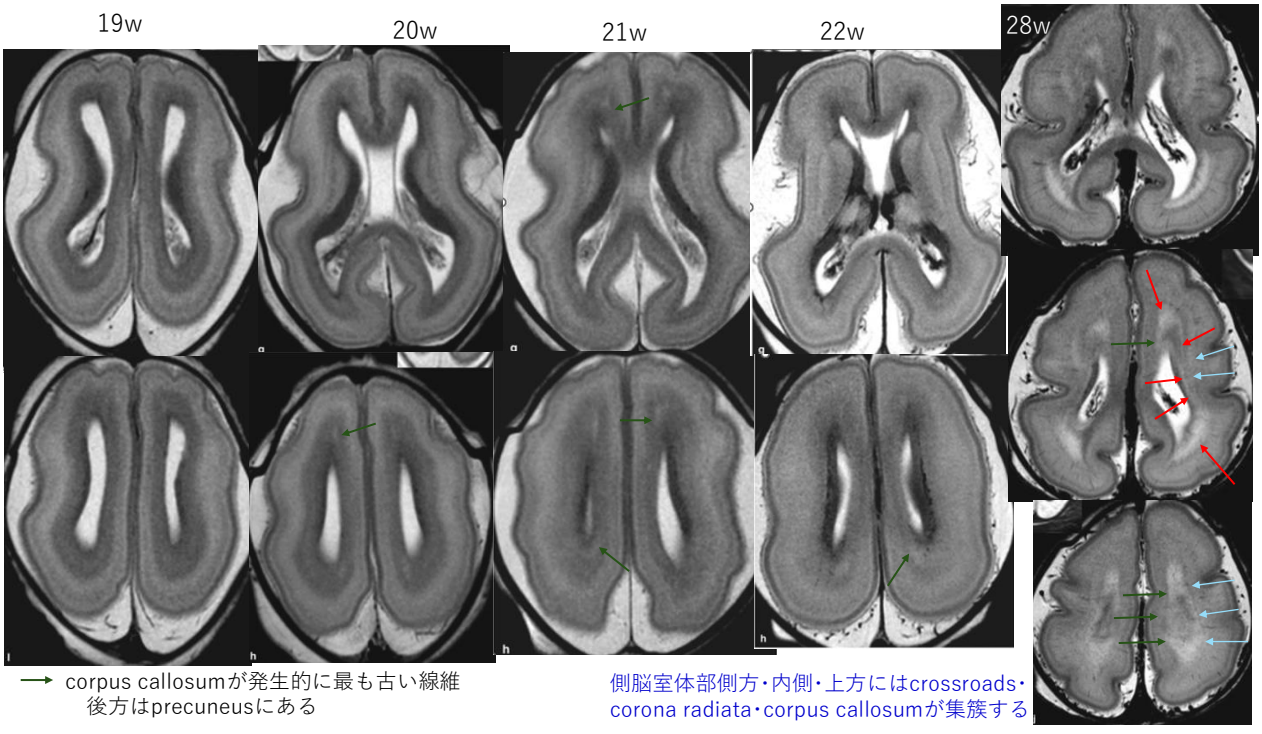
Multilaminar axonal-cell compartment
1: ventricular zone 2: inner subventricular zone 3: periventricular (callosal) fiber-rich zone
4: internal sagittal stratum(ISS)のinner proliferative cell layers(outer subventricular zone, OSVZ)
5: ISSのcell disperseのOSVZ 6: outer proliferative cell layer (OSVZ)
7: thalamocortical projection fibersの密なexternal sagittal stratum(ESS)で、その外縁はexternal capsule(ES)で、basal forebrainからの線維が走る
8: external transient proliferative cell band



T2高信号域は5-7 sagittal stratum (ISS・ESS)

Išasegi IZ, et al. Interactive histogenesis of axonal strata and proliferative zones in the human fetal cerebral wall. Brain Struct Funct. 2018; 223(9): 3919–3943.

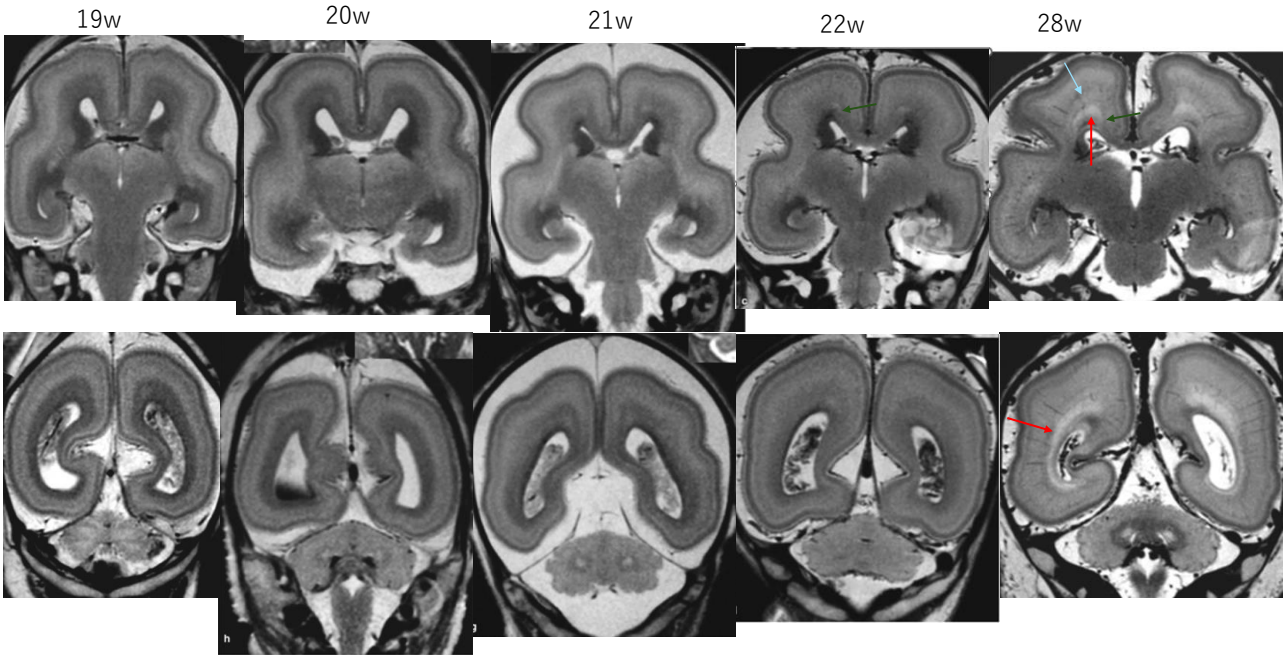
19



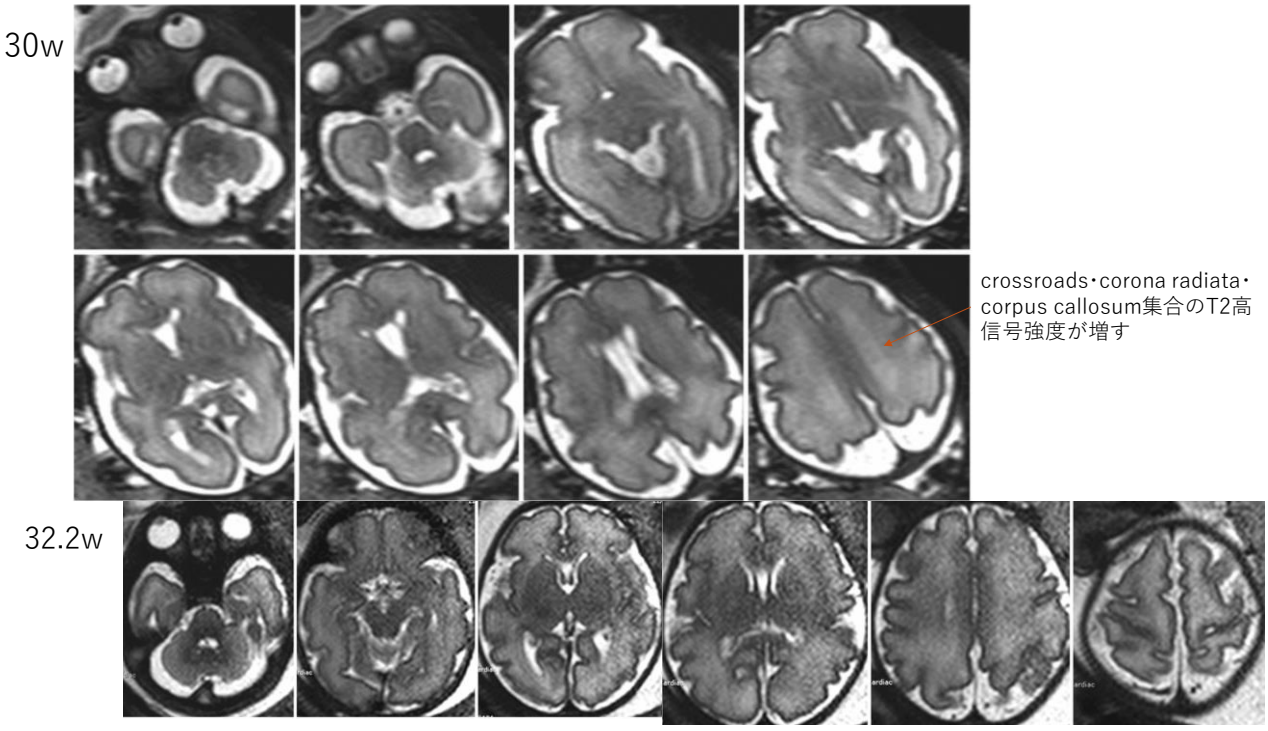
→ corpus callosumが発生的に最も古い線維
後方はprecuneusにある

側脳室体部側方・内側・上方にはcrossroads・corona radiata・corpus callosumが集簇する

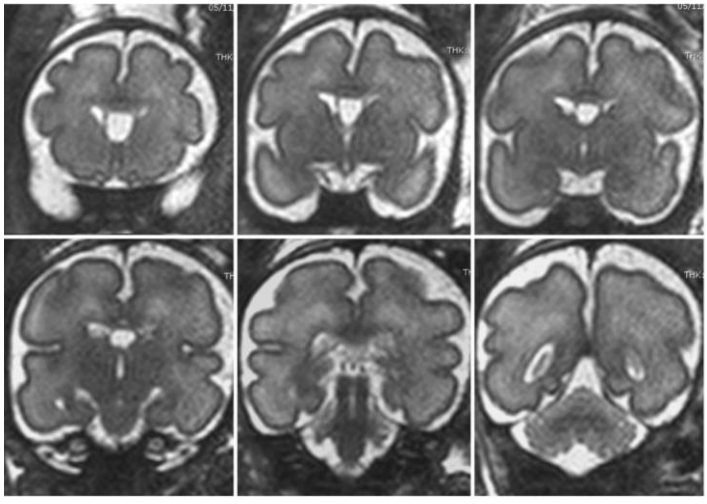
20


19w
20w
21w
22w
28w

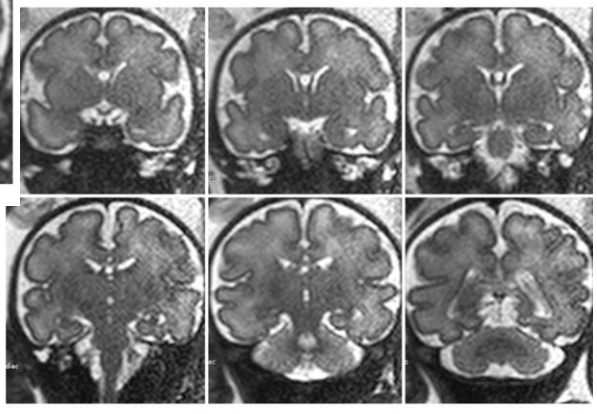
21


30w
crossroads・corona radiata・corpus callosum集合のT2高信号強度が増す
32.2w

22



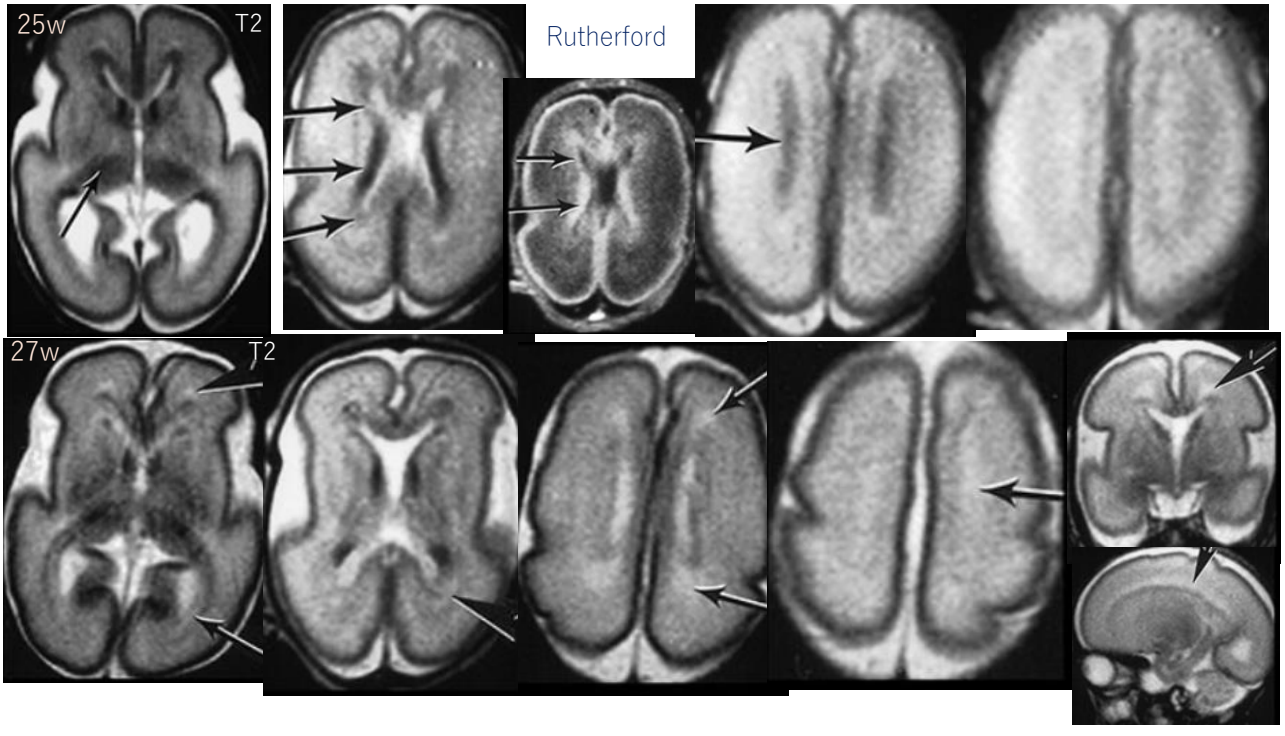
30w



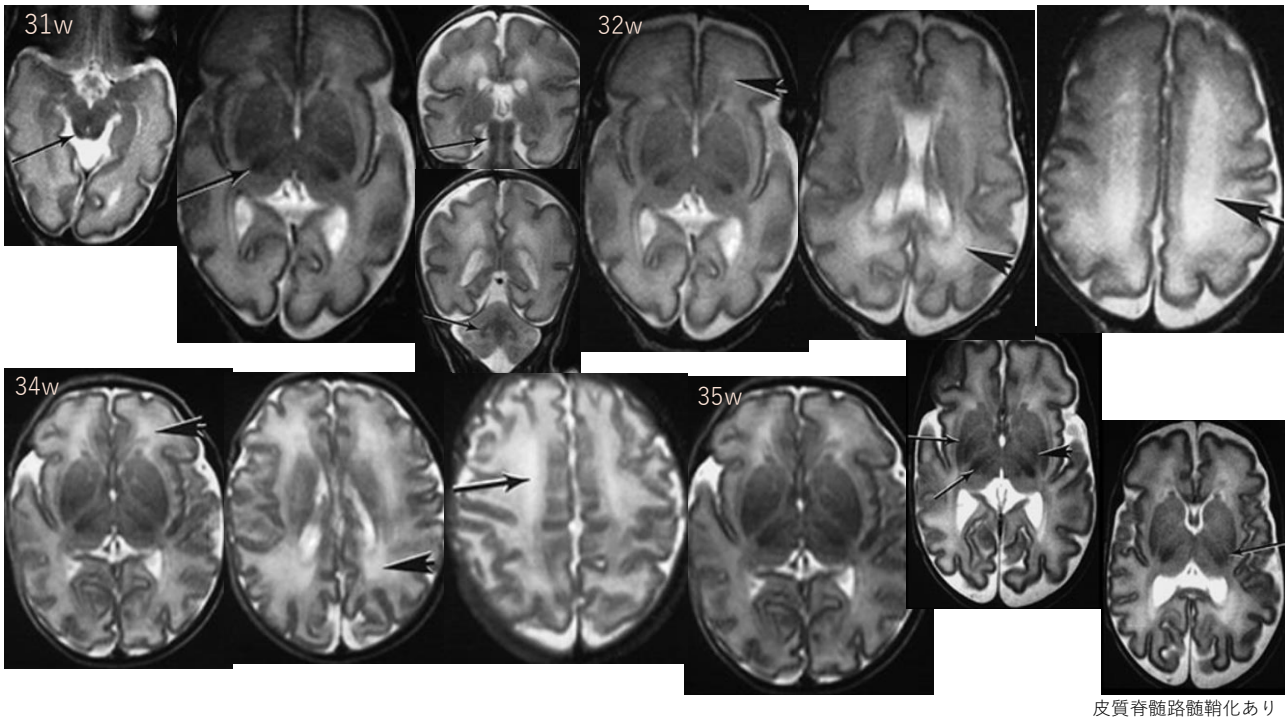
crossroads・corona radiata・corpus callosum
集合のT2高信号強度が増す

32.2w

23

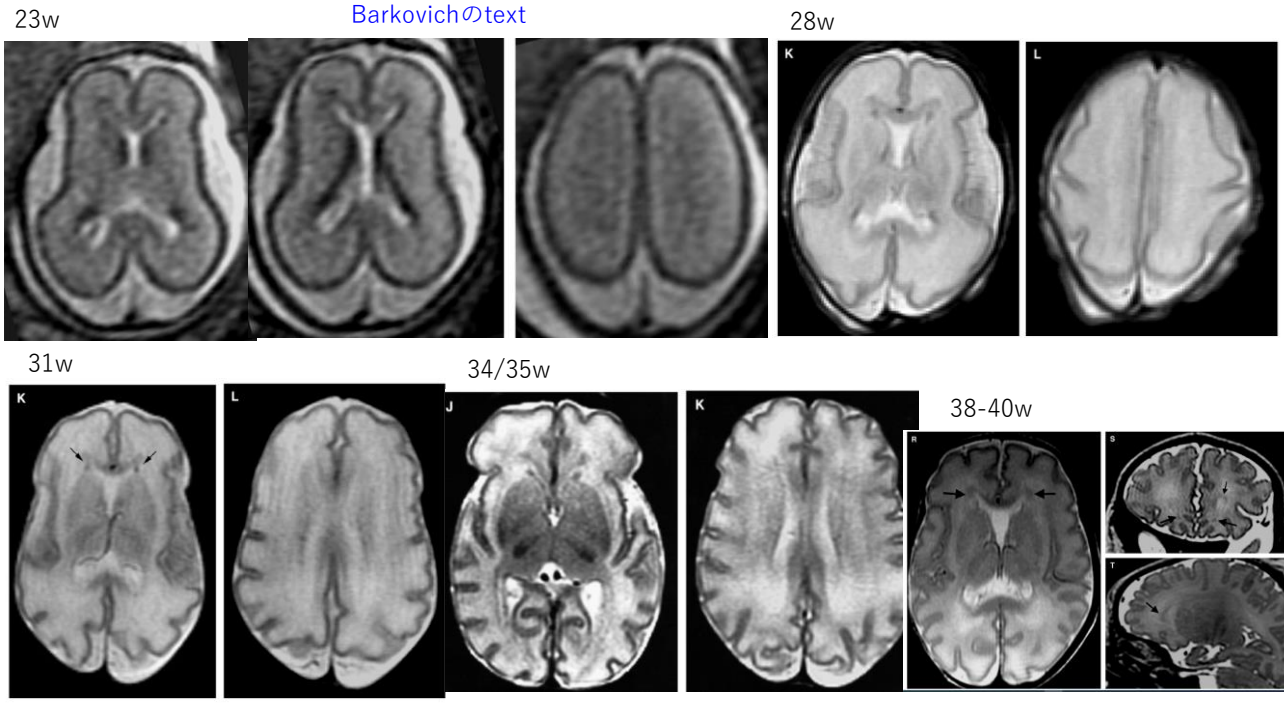


24

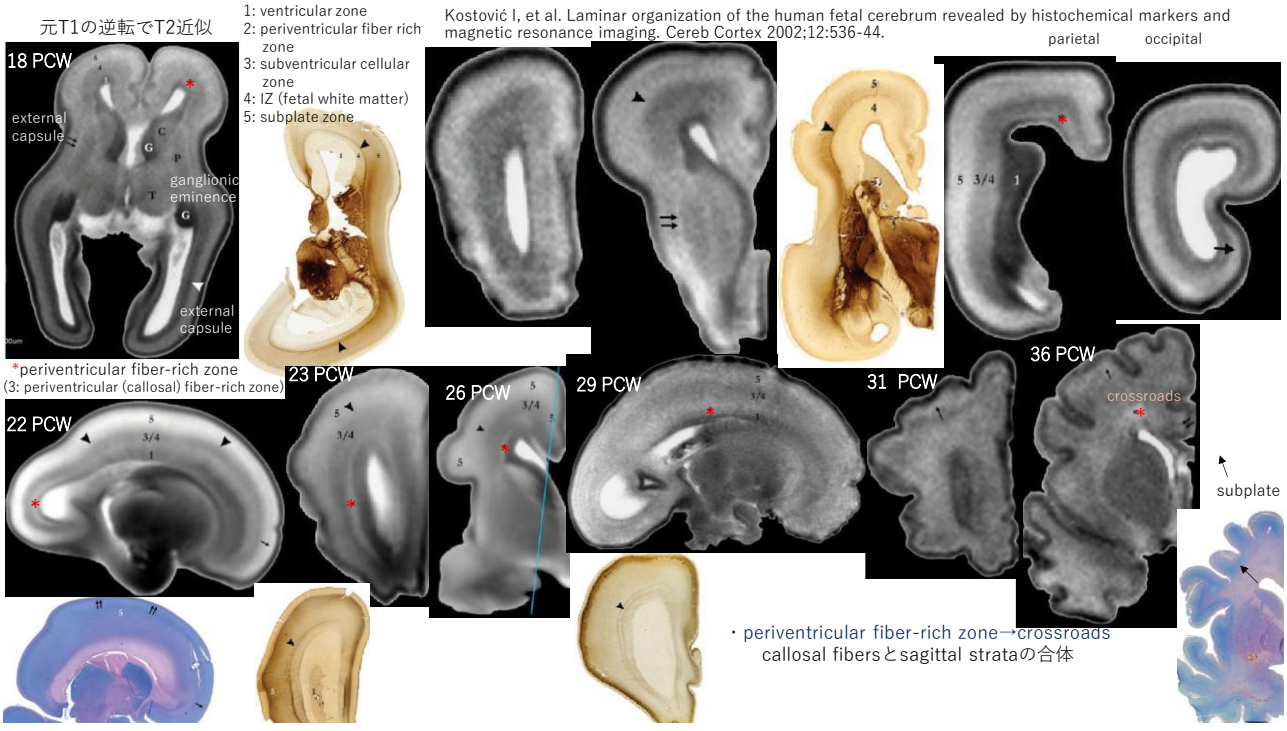


皮質脊髄路髄鞘化あり

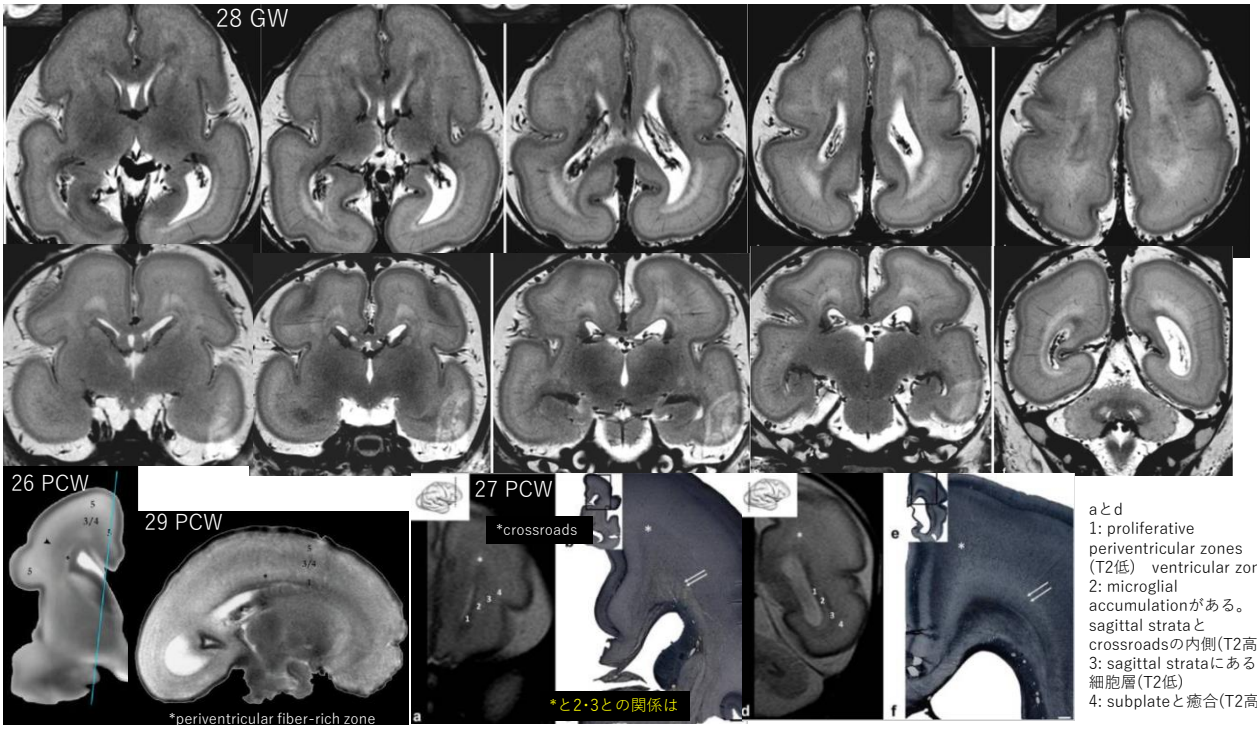
25



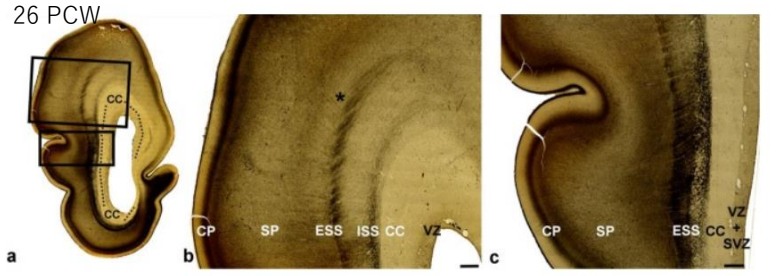
26


元T1の逆転でT2近似
1: ventricular zone
2: periventricular fiber rich zone
3: subventricular cellular zone
4: IZ (fetal white matter)
5: subplate zone
Kostović I, et al. Laminar organization of the human fetal cerebrum revealed by histochemical markers and magnetic resonance imaging. Cereb Cortex 2002;12:536-44.
parietal
occipital
18 PCW
external capsule
ganglionic eminence
external capsule
*periventricular fiber-rich zone
(3: periventricular (callosal) fiber-rich zone)
23 PCW
26 PCW
29 PCW
31 PCW
36 PCW
crossroads
22 PCW
subplate
・periventricular fiber-rich zone→crossroads
callosal fibersとsagittal strataの合体

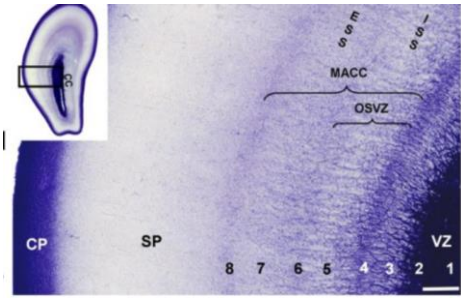
27

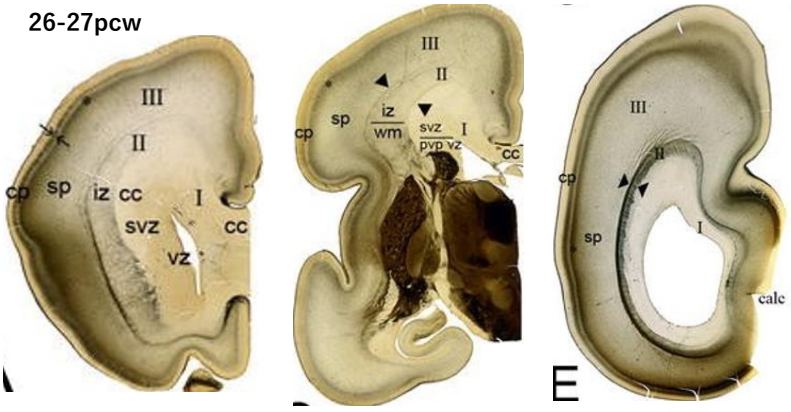

28 GW
26 PCW
29 PCW
*periventricular fiber-rich zone
27 PCW
*crossroads
*と2・3との関係は
aとd
1: proliferative periventricular zones (T2低) ventricular zone
2: microglial accumulationがある。sagittal strataとcrossroadsの内側(T2高)
3: sagittal strataにある細胞層(T2低)
4: subplateと癒合(T2高)

28



・3はCCまたはsegment I　・4-7はsagittal stratumまたはsegment II

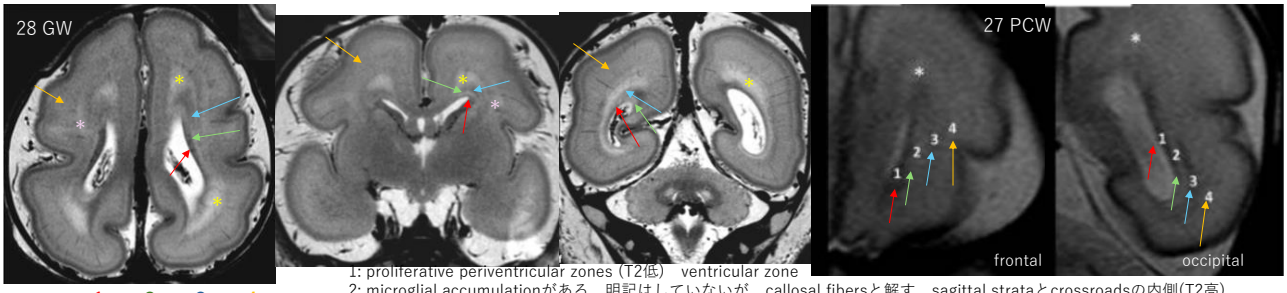




Crossroadsは~~segment II~~
segment I と II

Multilaminar axonal-cell compartment (MACC)
1: ventricular zone
2: inner subventricular zone
3: periventricular (callosal) fiber-rich zone
4: internal sagittal stratum(ISS)のinner proliferative cell layers(outer subventricular zone, OSVZ)
5: ISSのcell disperseのOSVZ
6: outer proliferative cell layer (OSVZ)
7: thalamocortical projection fibersの密なexternal sagittal stratum(ESS)で、その外縁はexternal capsule(ES)で、basal forebrainからの線維が走る
8: external transient proliferative cell band

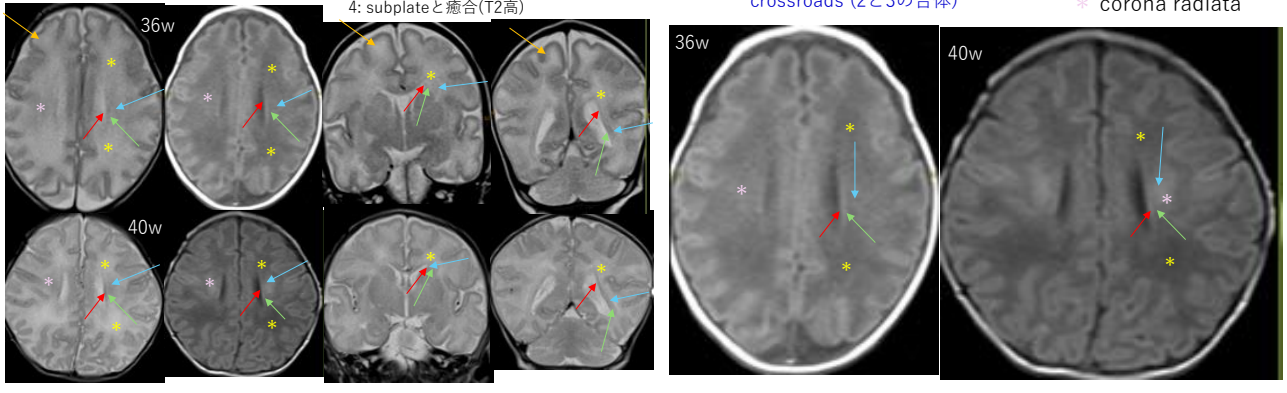
29



→1 →2 →3 →4

1: proliferative periventricular zones (T2低)　ventricular zone
2: microglial accumulationがある。明記はしていないが、callosal fibersと解す。sagittal strataとcrossroadsの内側(T2高)
3: sagittal strataにある細胞層(T2低)
4: subplateと癒合(T2高)

* crossroads (2と3の合体)　* corona radiata



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胎児脳外套T2高信号部はvulnerable

- crossroads

  25wではあり、32-34wがT2高信号のピークで、満期でも残る

- corpus callosum

  発生的に最も古い脳内線維である。20wで脳梁部はT2低信号であり(髄鞘化線維と高い細胞密度によるか)、その後その上にT2高信号の脳梁線維がのる。T2高信号程度は32-34wがピークで、満期でも線状にわずかに残る

- corona radiata

  27wにはT2高信号あり、32週がピークである。内側部は髄鞘化され、外上部のT2高信号が残る。満期にもわずかにある

✓早産白質障害には上記とは別に以下の病巣がある

・側脳室壁連続部 ・頭頂葉白質

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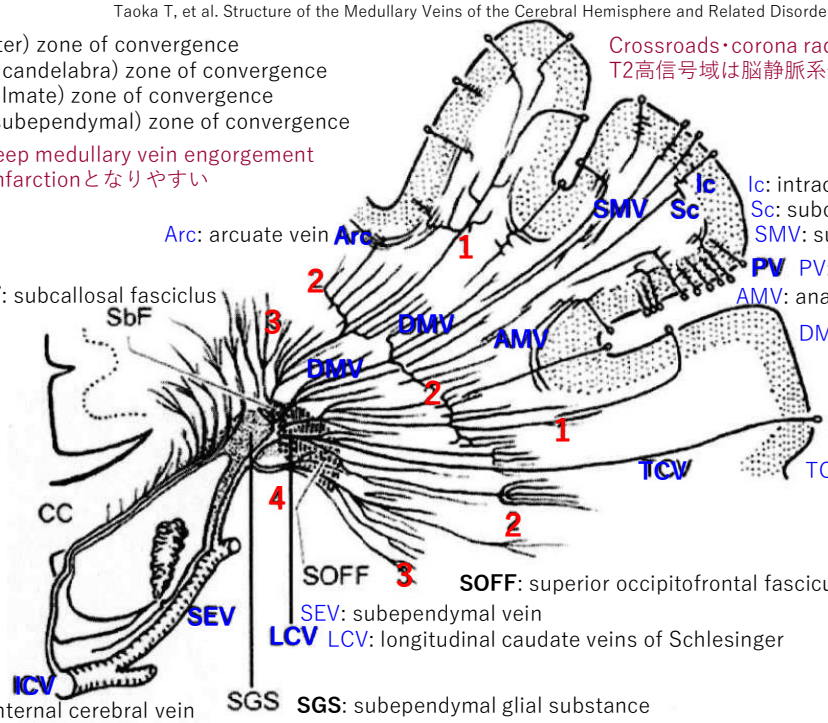
Taoka T, et al. Structure of the Medullary Veins of the Cerebral Hemisphere and Related Disorders. Radiographics 2017;37:281-297.

1: first (or outer) zone of convergence
2: second (or candelabra) zone of convergence
3: third (or palmate) zone of convergence
4: fourth (or subependymal) zone of convergence

この4部はdeep medullary vein engorgement
→ venous infarctionとなりやすい

Crossroads・corona radiata・corpus callosumの
T2高信号域は脳静脈系侵襲に弱い



Ic: intracortical vein
Sc: subcortical vein
SMV: superficial medullary vein
Arc: arcuate vein
PV: pial veins
AMV: anastomotic medullary vein
SbF: subcallosal fasciclus
DMV: deep medullary vein
TCV: transcerebral vein
SOFF: superior occipitofrontal fasciculus
SEV: subependymal vein
LCV: longitudinal caudate veins of Schlesinger
ICV: internal cerebral vein
SGS: subependymal glial substance

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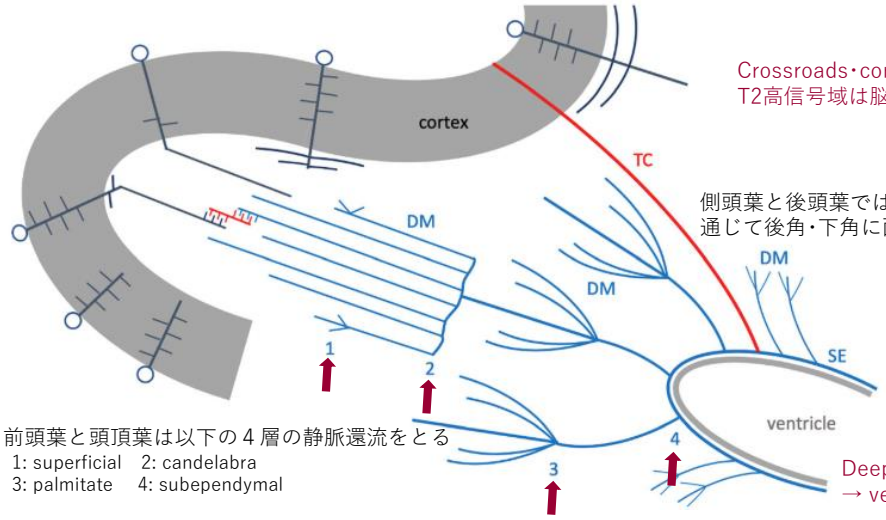
Khalatbari H, et al. Deep medullary vein engorgement and superficial medullary vein engorgement: two patterns of perinatal venous stroke. Pediatr Radiol 2021;51:675-685.



Crossroads・corona radiata・corpus callosumの
T2高信号域は脳静脈系侵襲に弱い

側頭葉と後頭葉では、transcerebral (TS) veinsを
通じて後角・下角に面する静脈に直接流入する

前頭葉と頭頂葉は以下の４層の静脈還流をとる
1: superficial　2: candelabra
3: palmitate　4: subependymal

Deep medullary vein engorgement
→ venous infarctionとなりやすい

The four zones of convergence of the deep medullary veins, the subependymal veins and the transcerebral veins. The deep medullary veins (DM) course centripetally to drain into the subependymal veins. Okudera et al. [13] demonstrated four zones of convergence in the frontal and parietal lobes by injecting barium into the internal jugular veins and obtaining radiographs of brain slices in cadavers. The zones of convergence from superficial to deep are **the superficial (1), candelabra (2), palmitate (3) and subependymal (4) zones**. In Zones 2 and 3 the medullary veins converge in characteristic configurations that resemble candelabras and palms, respectively. **Transcerebral (TC) veins** extend from the cortical surface to the subependymal veins. SE subependymal vein.

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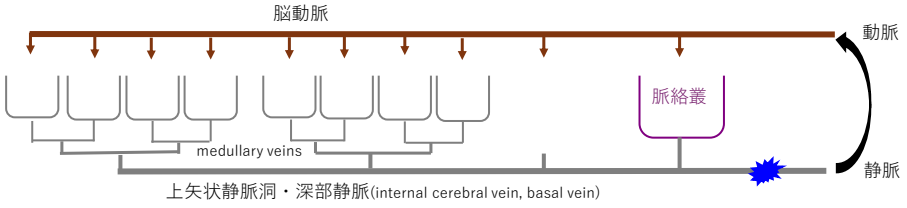
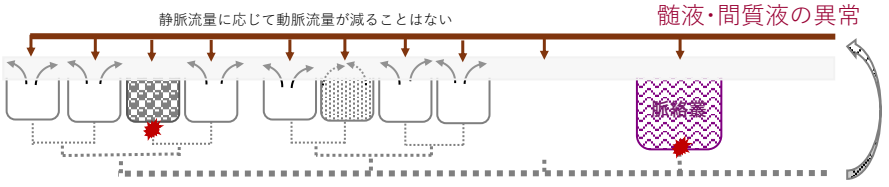


上矢状静脈洞・深部静脈が血栓で完全に閉塞したら、脳循環は廃絶し、脳機能は即座に停止する
→生存者では上矢状静脈洞・深部静脈が完全閉塞することはない。あったとしても一過性である



上矢状静脈洞・深部静脈がうっ滞したら、その上流はすべてうっ滞する
←凝固亢進、炎症性タンパクの増加、白血球の増加と運動亢進、内皮細胞の活動 etc　*流体力学変化*

→静脈怒張　→組織間液の増加　→白質変性　→白質低形成
→出血　→静脈梗塞　→髄液間質液の異常

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