

Paediatric Neurology

MARROW
— Super Speciality

Instructions

- The notes must be used in conjunction with the Marrow SS Paediatrics videos and should not be considered standalone material.

Please note:

- The information in this book has been printed based on the transcript of the Marrow SS Paediatrics videos.
- The information contained in this book is for educational purposes only. The content provided is not intended to substitute for professional medical advice, diagnosis or treatment.
- This book cannot be sold separately. It has been made available to only select eligible users who have an active subscription to Marrow SS Paediatrics videos.
- The text, images, slides, and other materials used in this book have been contributed by the faculty, who are subject matter experts. We have merely reproduced them as video transcripts in this book.
- The notes have been consciously designed in a way that is concise and revisable. To ensure this, we have intentionally added only the most relevant modules and images that are needed for you.
- Reasonable care has been taken to ensure the accuracy of the information provided in this book. Neither the faculty nor Marrow takes any responsibility for any liability or damages resulting from applying the information provided in this book.
- This set contains notes of all main videos published in the app until October 2025. You can find notes for any additional videos published after this date within the app under the videos section.

All Rights Reserved

No part of this publication shall be reproduced, copied, transmitted, adapted, modified or stored in any form or by any means, electronic, photocopying, recording or otherwise.

© Marrow

// ME811-PPL

Contents

Basics of Paediatric Neurology

1.	CNS Embryology & Basics of MRI Brain	1
2.	Congenital CNS Structural Malformations : Part I	10
3.	Congenital CNS Structural Malformations : Part II	15

Epilepsy

4.	Paediatric Epilepsy : Part I	29
5.	Paediatric Epilepsy : Part II	34
6.	Epilepsy Syndromes and Status Epilepticus	42
7.	Neonatal Seizures and Seizure Mimics in Children	58
8.	Neonatal & Infantile-Onset Epilepsy Syndromes	69
9.	Autoimmune Encephalitis & CNS Vasculitis	78

Disorders of Metabolism

10.	Introduction to Neurometabolic Diseases	87
11.	Amino Acid Metabolism Defects : Part I	95
12.	Amino Acid Metabolism Defects : Part II	103
13.	Disorders of Lipid Metabolism and Lipid Storage Disorders	115
14.	Inborn Errors of Carbohydrate Metabolism & Mitochondrial Disease	128

Cerebral Palsy and Stroke

15.	Cerebral Palsy	146
16.	Paediatric Stroke	159

Muscle Disorders

17.	Approach to Floppy Infant	176
18.	Muscle Disorders in Children : Part I	190
19.	Muscle Disorders in Children : Part II	201

Other Specific Conditions

20.	Paediatric Headache	209
21.	Neurocutaneous Diseases	223
22.	Neuropathies	240
23.	Neuronopathies : SMA	249
24.	Neuromuscular Junction Disorders	254
25.	CNS Demyelination Disorders	261
26.	Sleep Disorders in Children	272
27.	Movement Disorders in Children : Part I	286
28.	Movement Disorders in Children : Part II	305

Tumours

29.	Paediatric CNS Tumours	320
-----	------------------------	-----

Infections

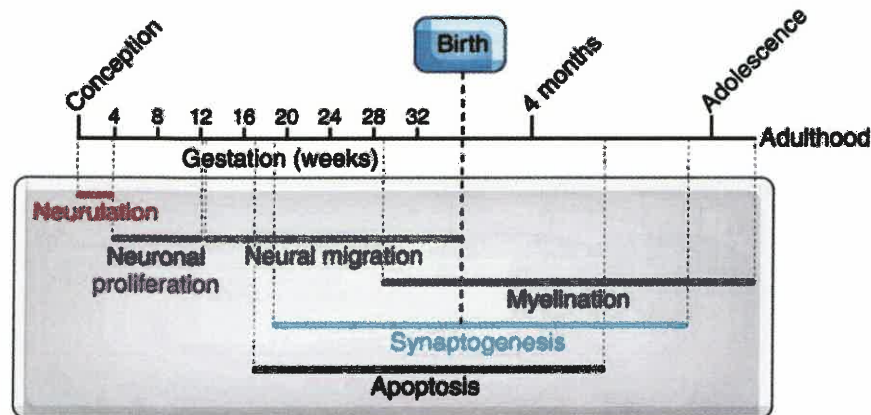
30.	Paediatric CNS Infections	331
-----	---------------------------	-----

CNS EMBRYOLOGY & BASICS OF MRI BRAIN

----- Active space -----

Embryology

00:00:22



Embryology timeline

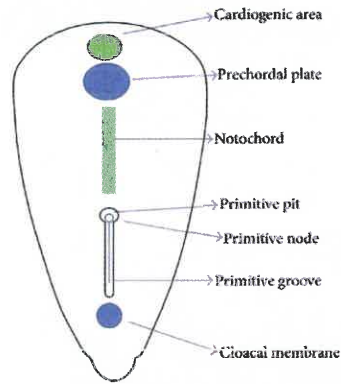
Timeline :

- Neurulation.
- Neuronal proliferation.
- Neural migration.
- myelination.
- Synaptogenesis.
- Apoptosis.

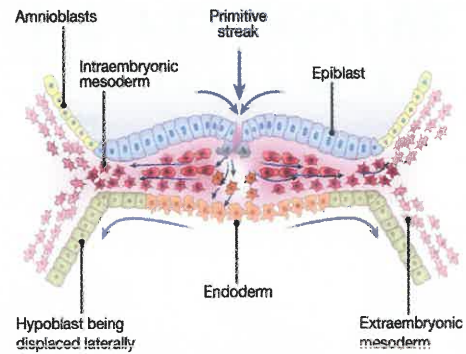
Gastrulation :

- Formation of a trilaminar embryonic disc : Endoderm, mesoderm and ectoderm.
- Gastrulation occurs in the 3rd week.
- Appearance of a **primitive streak** :
 - Initiates gastrulation.
 - Defines the major body axes.
- Gastrulation precedes and is critical for neurulation.
- Cells from the primitive pit travel to the cephalad and form notochord in the mesoderm (**Induction**).
- Notochord induces formation of a plate of ectodermal cells dorsally in the midline : Neural ectoderm, which later develops into a neural plate.
- Ectoderm : Surface ectoderm and neural ectoderm.

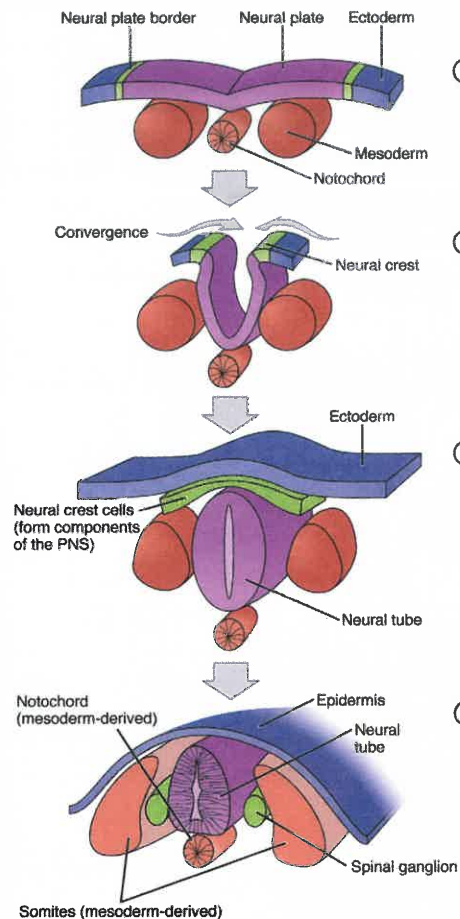
----- Active space -----



Formation of primitive streak



Gastrulation : Formation of germ layers



Formation of primitive streak, gastrulation & notocord

① Neuroectodermal tissues differentiate from the ectoderm and thicken into the neural plate. The neural plate border separates the ectoderm from the neural plate.

② The neural plate bends dorsally, with the two ends eventually joining at the neural plate borders, which are now referred to as the neural crest.

③ The closure of the neural tube disconnects the neural crest from the epidermis. Neural crest cells differentiate to form most of the peripheral nervous system.

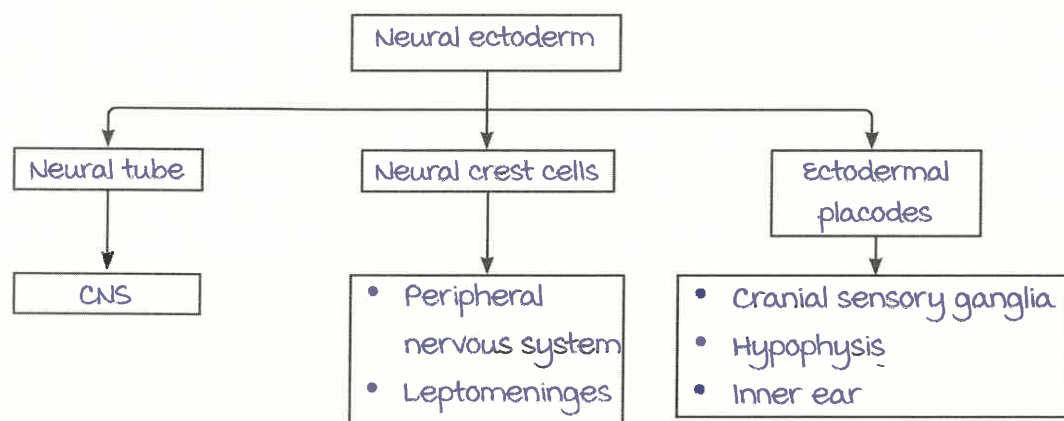
④ The notochord degenerates and only persists as the nucleus pulposus of the intervertebral discs. Other mesoderm cells differentiate into the somites, the precursors of the axial skeleton and skeletal muscle.

Neurulation :

- At day 17, lateral portions of the neural plate begin to thicken forming neural folds.
- Contractile elements of neuroepithelial cells cause the neural tube to fold dorsally and fuse in the midline.
- Neurulation begins when the neural folds meet in the midline.
- Disjunction is the separation of the closed neural tube from the cutaneous ectoderm.

----- Active space -----

- **Anterior neuropore** : Eventually forms the brain, closes approximately by day 26. (If not closed : **encephalocele**).
- **Posterior neuropore** : Eventually forms the caudal spinal column, closes approximately by day 29 (If not closed : **meningomyelocele**, **Spina bifida**).
- **Neural crest cells** : Arise from the neural plate's lateral edges during the neural tube formation.
- Some areas of neuroepithelium become incorporated into the surface ectoderm : **Ectodermal placodes**.



CNS cells :

- Neuronal.
- Non neuronal :
 - macroglia : Astrocytes, ependymal cells & oligodendrocytes.
 - microglia.

microglia : **mesodermal** in origin.

Neuronal cells and macroglia : Ectodermal in origin.

Leptomeninges : Origin is from surface ectoderm.

Duramater : mesodermal in origin.

Development of brain

00:14:08

Overview :

Following complete closure of neural tube → Divisible into an enlarged cranial part and an elongated caudal part, which later gives rise to the brain and spinal cord, respectively.

Brain vesicles :

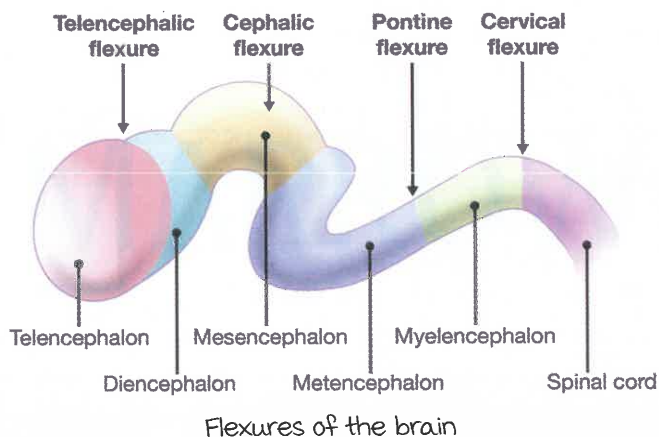
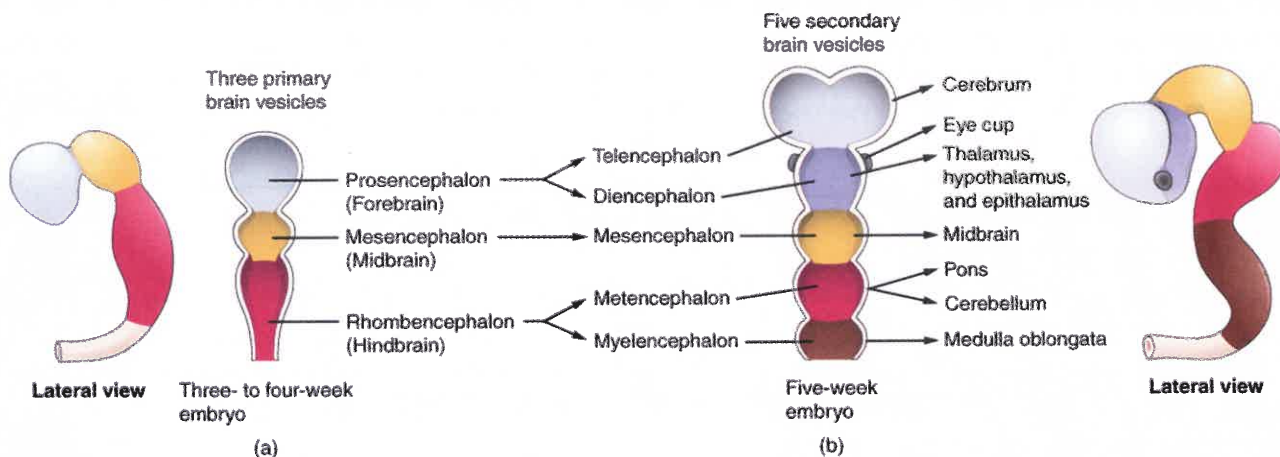
- With the closure of the anterior neuropore, three brain vesicles develop.
- The three subdivisions are prosencephalon, mesencephalon and rhombencephalon.

----- Active space -----

3 flexures of the brain :

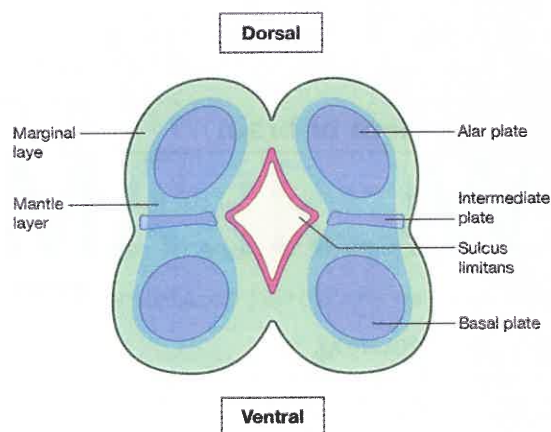
1. Cranial (mesencephalic)
2. Cervical flexures ventrally

3. Pontine flexure dorsally.



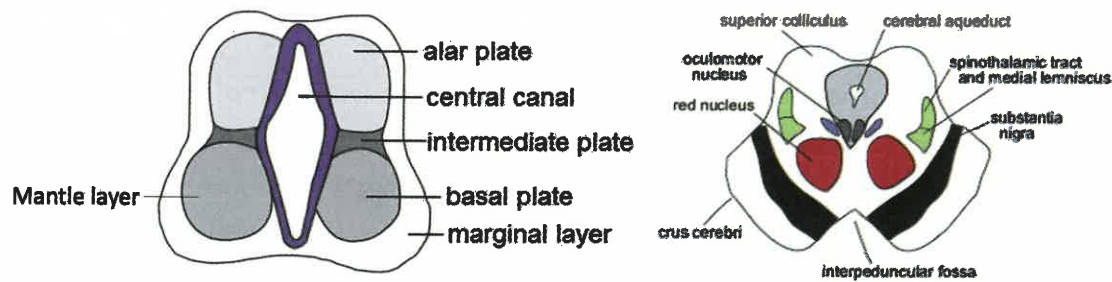
Cross section of neural tube :

- A longitudinal groove (Sulcus limitans) divides the neural tube into two parts or laminae : Alar plate and basal plate.
- Alar plate lies dorsally and gives rise to sensory neurons (SAD).
- Basal plate lies ventrally and gives rise to motor neurons (mbv).
- marginal layer develops into white matter.
- mantle layer develops into grey matter.



mesencephalon to midbrain :

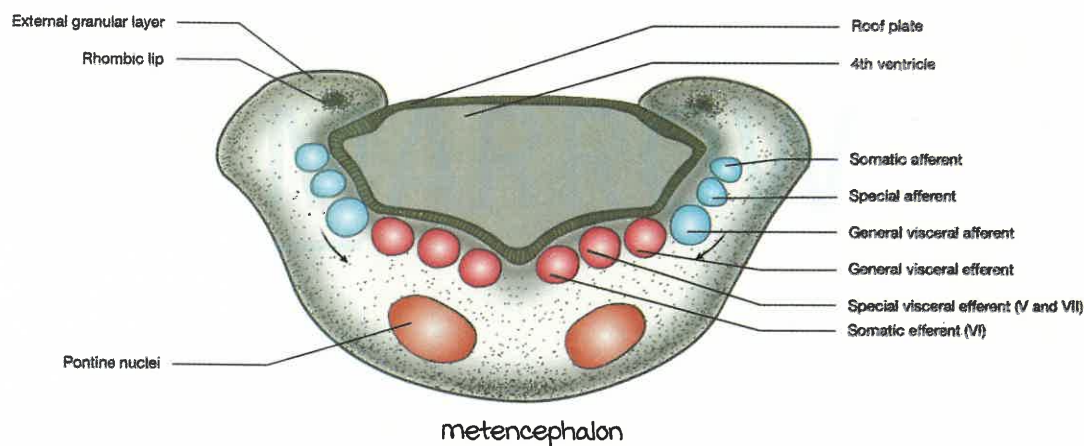
----- Active space -----



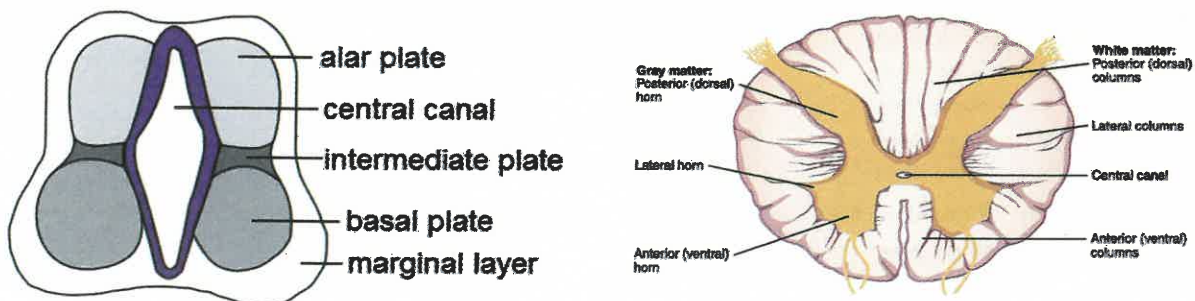
- marginal layer → white matter.
- marginal layer : Proliferates ventrally → Forms crus cerebri.

metencephalon to pons and cerebellum :

- In the rhombencephalon, the walls of the neural tube splay open dorsally → Roof plate is stretched and widened.
- **Rhombic lip** : Dorsal margin of the alar plate, adjoining the massively expanded roof plate.
- The rhombic lip → Cerebellar plates and later the cerebellum.
- The alar plate cells → Pontine nuclei.



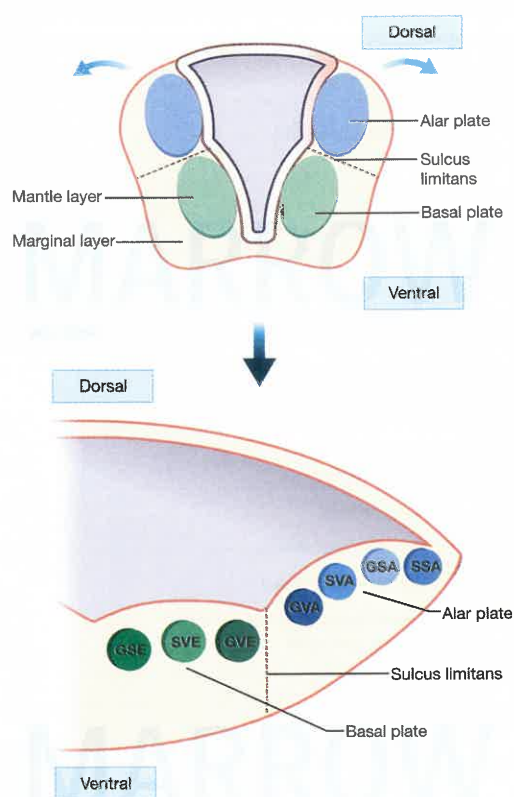
myelencephalon to medulla oblongata :



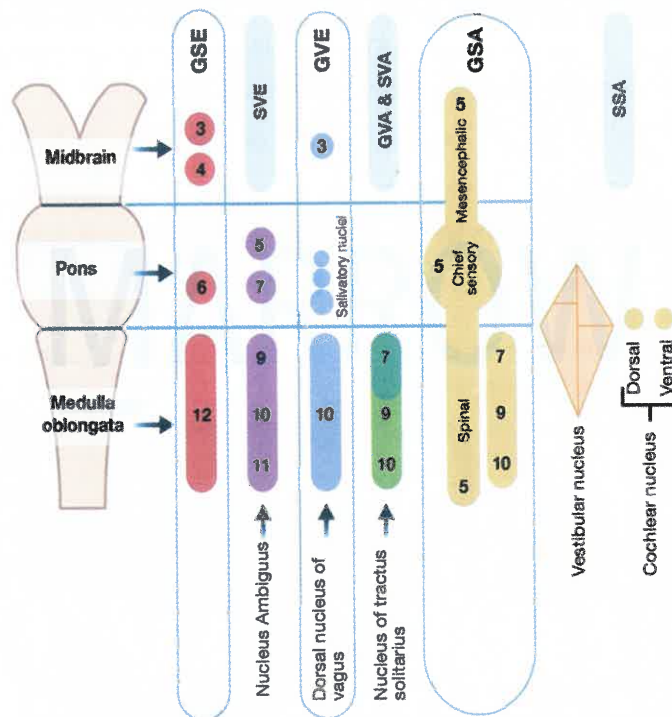
Brain stem nuclei

Arrangement :

- Cells in each lamina (Alar and basal) organize into longitudinal columns : visceral and somatic.
- Somatic components : Derivatives of 'somites' derived from mesoderm.
- All striated muscles of limbs and body wall and muscles of extraocular movements and tongue are somatic.
- Visceral components lie close to the sulcus limitans.
- Another special column appears between visceral and somatic columns : Supply derivatives of pharyngeal arches.



Arrangement of nuclei in the brainstem of embryo



Nuclei derived from each column in brainstem of adult (ventral to dorsal)

Cranial nerve nuclei derived from various functional columns in the brainstem :

----- Active space -----

GSE column	SVE column	GVE column	GVA/SVA column	GSA column	SSA column
Oculomotor nucleus	motor nucleus of trigeminal nerve	Edinger-Westphal nucleus	Nucleus of solitary tract (Nucleus tractus solitarius)	Sensory nuclei of trigeminal nerve	Vestibular nuclei
Trochlear nucleus	motor nucleus of facial nerve	Lacrimal nucleus	-	1. Chief	Cochlear nuclei
Abducent nucleus	Nucleus ambiguus	Superior salivatory nucleus	-	2. mesencephalic	-
Hypoglossal nucleus	-	Inferior salivatory nucleus	-	3. Spinal	-
-	-	Dorsal nucleus of vagus nerve	-	-	-

Major events in human brain development

00:31:50

major events in human brain development :	
Gastrulation	3 weeks POG
Primary neurulation	3-4 weeks POG
Prosencephalic development	2-3 months POG
Neuronal proliferation	3-4 months POG
Neuronal migration	3-5 months POG
Organisation	5 months-years postnatally
Myelination	Birth to years postnatally

Development of cerebral cortex :

- Neuroblasts proliferate in the ventricular zone & later in the subventricular zone → F/b migration towards the marginal layer through radial migration.
- Projection neurons undergo radial migration.
- Inhibitory interneurons undergo tangential migration.
- The early generated neurons form the initial cortical plate and later generated neurons climb past them to become progressively more superficial → **Inside out pattern**.
- The marginal layer → Layer 1 of the cortex.
- The earliest neurons to migrate → Layer 6
- Last to migrate neurons → Layer 2.
- 6 layered cortex : Formed by 24 to 27 weeks.
- Further organization in the form of myelination, synaptic maturation, gyri, sulci formation continues even postnatally.

----- Active space -----

Basics of MRI brain

00:36:30

3 major sequences :

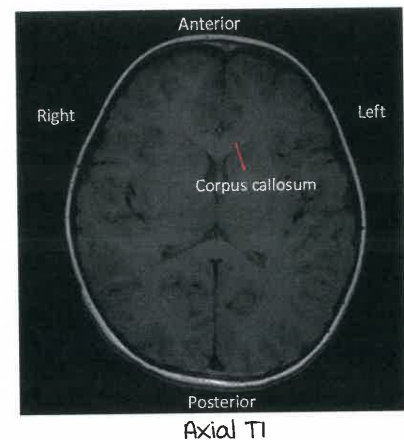
- T1.
- T2.
- T2 FLAIR.

3 views :

- Axial.
- Sagittal.
- Coronal.

Axial T1 :

- White matter is white.
- Grey matter is dark.
- CSF is black.
- Good for structural malformations.

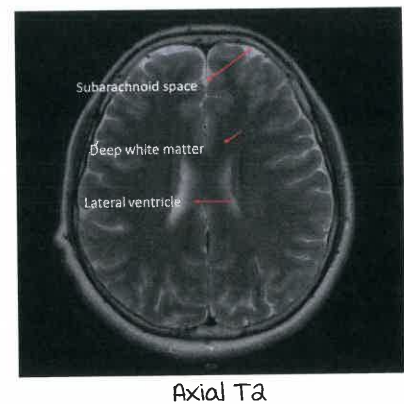
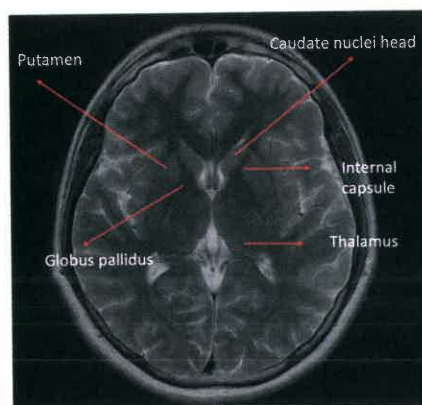
**T1 bright :**

- Fat (myelin).
- melanin.
- Subacute bleed.
- manganese, copper.
- Contrast.
- Posterior pituitary gland.

Axial T2 :

- White matter is dark.
- Grey matter is light.
- CSF is white.

World War 2 : Water white on T2

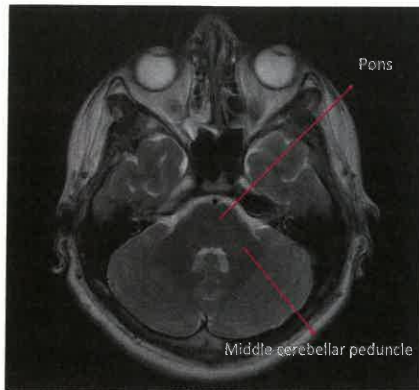


Basal ganglia

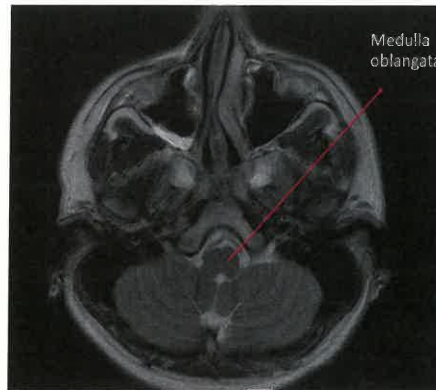


midbrain

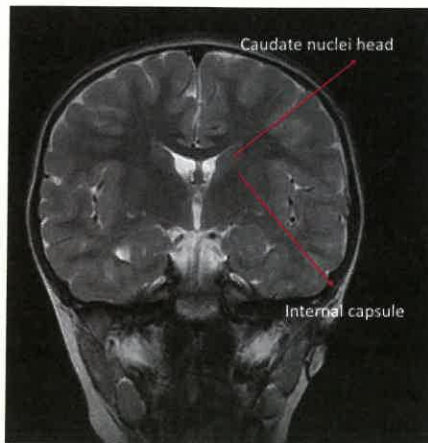
----- Active space -----



Pons



medulla



Coronal T2



Axial T2 FLAIR

Axial T2 FLAIR :

- T2 weighted sequence.
- Fluid/CSF : Dark.
- White matter lesions are highlighted.

----- Active space -----

CONGENITAL CNS STRUCTURAL MALFORMATIONS : PART I

Neural tube defects

00:00:21

Introduction :

- Results from the failure of the neural tube to close spontaneously between 3rd and 4th week of gestation.
- m/c congenital anomalies of CNS.
- major NTDs (Neural Tube Defects) include : Spina bifida occulta, meningocele, myelomeningocele, encephalocele, anencephaly, caudal regression syndrome, dermal sinus, tethered cord, syringomyelia, diastematomyelia, lipoma involving the conus medullaris and/or filum terminale and iniencephaly.

Risk factors for NTD :

- maternal hyperthermia.
- Drugs : Valproic acid, phenytoin.
- malnutrition.
- Low red cell folate levels, chemicals, maternal obesity or diabetes.
- Genetic determinants : mutations in folate pathways.

Risk of recurrence :

- Affected child : 3-4%.
- 2 affected children : 10%.

Prevention :

- maternal periconceptional use of folic acid supplementation : Reduces the incidence of NTDs by at least 50%.
- Initiated before conception and continued until at least the 12th week of gestation, when neurulation is complete.
- Dose : 0.4 mg (4 mg in those with previous pregnancy with NTD).

Screening :

- Failure of closure of the neural tube allows excretion of fetal substances : Alpha-fetoprotein (AFP) and acetylcholinesterase into the amniotic fluid.
- Prenatal screening of maternal serum for AFP in the 16th-18th week of gestation : Detect NTD.

Closed spinal cord malformations :

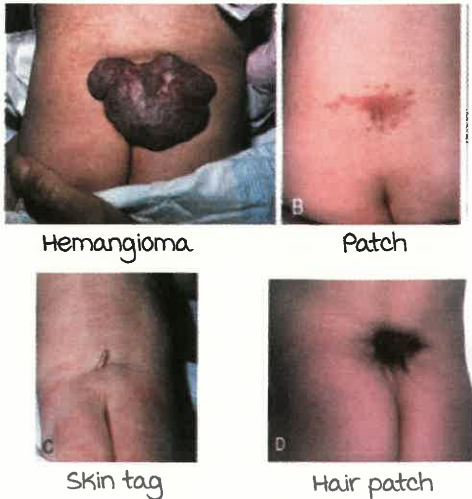
----- Active space -----

Spina bifida occulta :

- midline fusion defect of posterior vertebral body with no spinal cord protrusion.
- No clinical symptoms or neurological signs.

Occult spinal dysraphism :

- Clinically significant closed spinal cord malformations.
- Syringomyelia, diastematomyelia, lipoma, fatty filum, dermal sinus, tethered cord.
- most have cutaneous stigmata.

**Imaging Indicated**

Subcutaneous mass or lipoma
 Hairy patch
 Dermal sinus or cyst
 Atypical dimples (deep, > 5 mm, > 25 mm from anal verge)
 Vascular lesion, e.g., hemangioma or telangiectasia
 Skin appendages or polypoid lesions, e.g., skin tags, tail-like appendages
 Scar-like lesions (aplasia cutis)

Imaging Uncertain

Hyperpigmented patches
 Deviation of the gluteal fold

Imaging not Required

Simple dimples (< 5 mm, < 25 mm from anal verge)
 Coccygeal pits

Cutaneous lesions associated
 with Occult Spinal Dysraphism

meningocele :

- meninges herniate through a defect in the posterior vertebral arches/ anterior sacrum.
- Spinal cord : usually normal in position.
- most have intact overlying skin.
- Patients with leaking CSF or a thin skin covering should undergo immediate surgical treatment to prevent meningitis.
- CT scan/MRI of the head : Recommended for children with a meningocele because of the association with hydrocephalus.

myelomeningocele (MMC) :

- m/c neural tube defect.
- m/c location : Lumbosacral region (75%).

----- Active space -----

Clinical manifestations :

- Depend on location and associated lesions.
- Flaccid paralysis of the lower limbs, absent DTRs, loss of touch and pain.
- High incidence of lower extremity deformities : Clubfeet, ankle and/or knee contractures and subluxation of the hips.
- Bowel and bladder incontinence.

Complications :

- Hydrocephalus with cerebellar herniation and thin elongated medulla in 80% cases : Chiari 2 malformation/**Arnold Chiari malformation**.
- **Chiari crisis** :
 - Symptoms of brainstem dysfunctions in Chiari 2.
 - Feeding difficulty, choking, stridor, apnoea, vocal cord paralysis, pooling of secretions and spasticity.

Surgery :

- MMC repair within 72 hours in case of CSF leak.
- Followed by hydrocephalus management by ventriculoperitoneal (**VP**) shunt.

most important prognostic factors :

- Renal complications.
- Tethered cord.

Skull dysraphisms :

Cranial meningocele : CSF-filled sac protruding through skull defect.

Cranial meningoencephalocele :

- Part of the cerebral cortex or cerebellum or brainstem also along with the sac.
- Occipital region : m/c site.

meckel Gruber syndrome :

- Autosomal recessive.
- Triad of **occipital encephalocele**, **polycystic kidney** and **post-axial polydactyly**.

moms study :

----- Active space -----

management of myelomeningocele study :

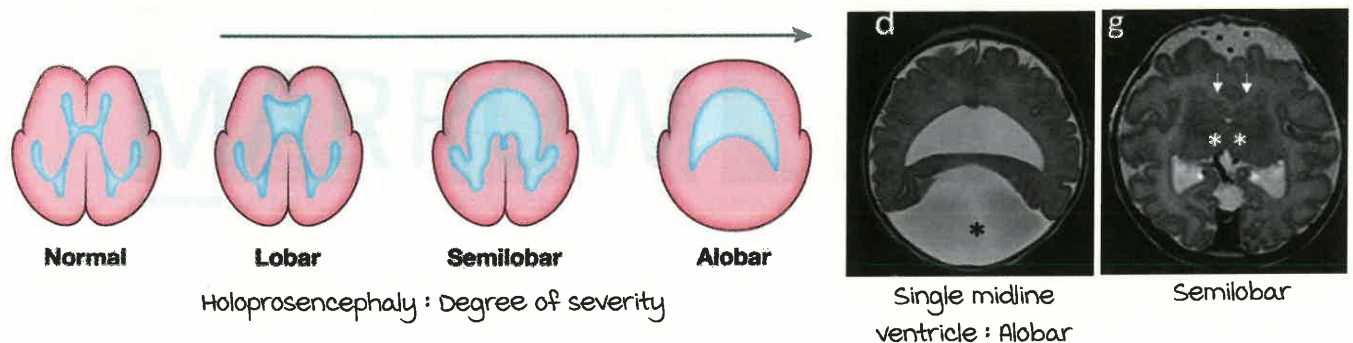
- Randomized controlled trial assessing prenatal repair of MMC vs post natal repair.
- **Primary outcome** : Death or need for VP shunt at 12 months.
- Statistically significant results in prenatal repair group.
- Study terminated based on the interim results of positive efficacy.

Disorders of forebrain development

00:16:07

Holoprosencephaly :

- Defective formation of the prosencephalon and inadequate induction of forebrain structures.
- Types : Alobar, semi lobar, lobar and syntelencephaly.
- Facial abnormalities associated with severe cases : Cyclopia, synophthalmia, cebocephaly, single nostril, choanal atresia, solitary central incisor tooth and premaxillary agenesis.
- Associated with **sonic hedgehog gene (SHH)** mutations.

**Septo-optic dysplasia :****Triad of :**

- Optic nerve hypoplasia.
- Pituitary abnormalities.
- midline brain defects (Involving septum pellucidum or corpus callosum).

Clinical presentation :

- Features of pituitary hormone abnormalities : Hypoglycemia, microphallus at birth, growth failure and other endocrine manifestations throughout childhood.
 - Pituitary insufficiency management is crucial.
- Nystagmus, midline cranial defects : Cleft lip or palate.
 - Any child with nystagmus should be evaluated for optic nerve hypoplasia and anterior pituitary insufficiency

----- Active space -----

Associated genes :

- HESX1.
- SOX2.

Agenesis of corpus callosum :

m/c birth defect of CNS after spina bifida.

Development of corpus callosum : From commissural plate that lies in proximity to the anterior neuropore.

MRI :

- Widely separated frontal horns with an abnormally high position of the third ventricle between the lateral ventricles.
- Racing car in axial section.
- Viking helmet appearance in coronal section.



Axial view : Parallel frontal horns of lateral ventricle



Cross-section : Viking helmet sign



Sagittal view : No corpus callosum

Etiology :

- Genetic : Trisomy 8 and 18.
- Non-genetic factor : Fetal alcohol syndrome.

Aicardi syndrome :

- Triad : Corpus callosum agenesis, chorioretinal lacunae and infantile spasms.
- Exclusively seen in girls.