Neonatal and Infant Head

Chapter 27

1

Objectives:

- Upon completion of this presentation, students will be able to:
  - Describe embryology of neonatal brain development
  - Identify normal neonatal and infant normal neuroanatomy
  - Describe exam preparation and protocol related to neurosonography
  - Recognize pathology related to neonatal and infant heads

2

Neurosonography

- Primary imaging modality for high-risk and unstable premature infants because it is portable, nonionizing, noninvasive, and can be tolerated by the sickest infants, even immediately after birth
- Reliable tool for the detection of most hemorrhage cystic and ischemic brain lesions, structural brain anomalies, calcifications, and cerebral infections

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Neurosonography (cont'd)

- Neurologic impairment one of the primary concerns about the health of premature infants
- Intraventricular and subependymal hemorrhages occur in 40-70% of premature neonates under 34 weeks of gestation
- Multifocal necrosis of the white matter, referred to as periventricular leukomalacia (PVL), may develop in 12-20% of infants weighing less than 2000 g (5lb 5oz)

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Embryology

- Central nervous system develops from neural plate
- Neural plate
  - Develops at 18 to 20 days after conception
  - Forms the neural tube and neural crest
- Neural tube differentiates into CNS
  - Consisting of both brain and spinal cord
- Neural crest gives rise to most of the structures in peripheral nervous system

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Embryology (cont'd)

- Walls of tube thicken to form various portions of the brain and spinal cord
- Lumen of neural tube becomes the ventricular system of the brain cranially and central canal of spinal cord caudally
- Greatest growth and differentiation of neural tube are at the cranial end
- At end of 4th week conception cranial end of neural tube differentiates into three primary brain vesicles
  - Prosencephalon (forebrain)
  - Mesencephalon (midbrain)
  - Rhombencephalon (hindbrain)

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Embryology (cont'd)

- Following week
  - Forebrain differentiates into:
    - Telencephalon (end brain)
      - "Rostral portion" of brain
    - Diencephalon (immediate brain)
  - Hindbrain divides into:
    - Metencephalon
    - Myelencephalon

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Progression of Developing Regions of Brain

Primary Brain Vesicles	Secondary Brain Vesicles	Regions of Mature Brain
Forebrain	Diencephalon	Thalamus, epithalamus, hypothalamus, subthalamus
	Telencephalon	Cerebral hemispheres (consisting of cortex and medullary center, corpus striatum, and olfactory system)
Midbrain	Mesencephalon	Midbrain
Hindbrain	Myelencephalon	Medulla
	Metencephalon	Pons and cerebellum

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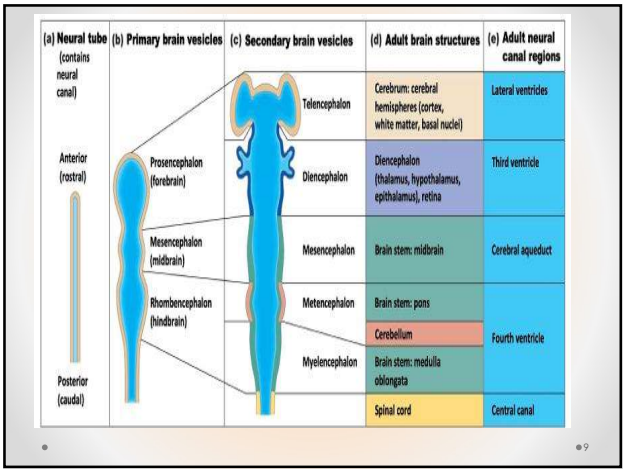

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Anatomy of Neonatal Brain

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Fontanelle

- Spaces between the bones of the skull
  - Allow for compression at birth and rapid brain growth thereafter
- In neonates
  - Have not closed completely
- Transducer is placed carefully on fontanelle to record multiple images in
  - Coronal
  - Axial
  - Sagittal

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Sutures

- They are immovable; however, essential to have some space to allow for the rapid growth of brain development and maturity
- Allow for molding for birth passage
- Craniosynostosis – premature closing either prenatally or postnatally that can result in increased brain pressure
  - Abnormal shaped skull is a visual indication

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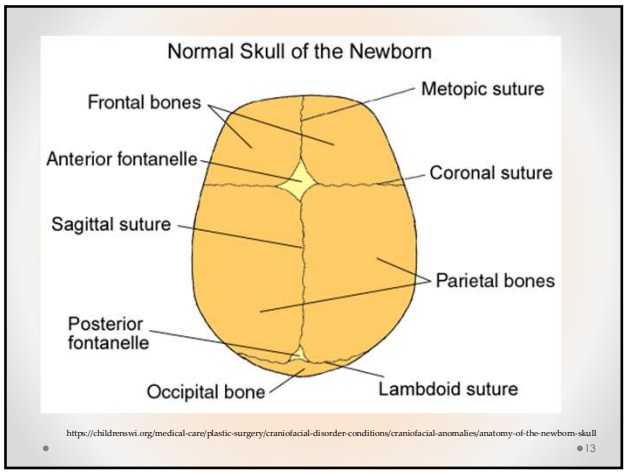

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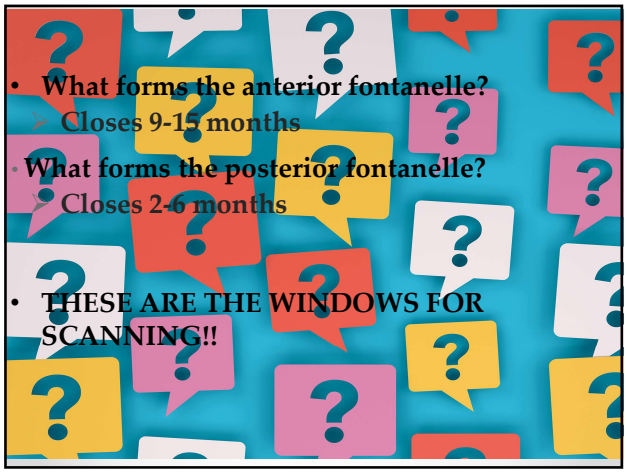

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Meninges

- Three membranes surround and form a protective covering for the brain
  - Dura mater
    - Double layered outer membrane ("tough mother")
  - Arachnoid mater- middle layer
  - Pia mater- inner layer ("soft mother")
- Falx cerebri
  - Fibrous structure that separates two cerebral hemispheres
- Tentorium cerebelli
  - V-shaped echogenic structure that separates cerebrum and cerebellum
    - Extension of falx cerebri
    - Infratentorial structures of brain collectively referred to as the posterior fossa

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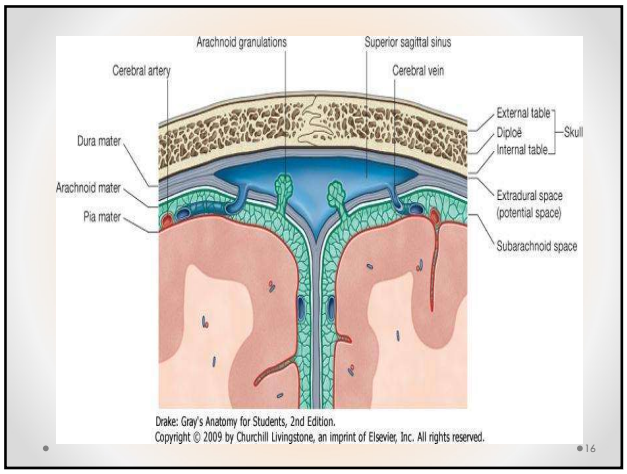
Arachnoid granulations
Superior sagittal sinus
Cerebral artery
Cerebral vein
External table
Diploë
Internal table
Skull
Dura mater
Arachnoid mater
Pia mater
Extradural space
(potential space)
Subarachnoid space
Drake: Gray's Anatomy for Students, 2nd Edition.
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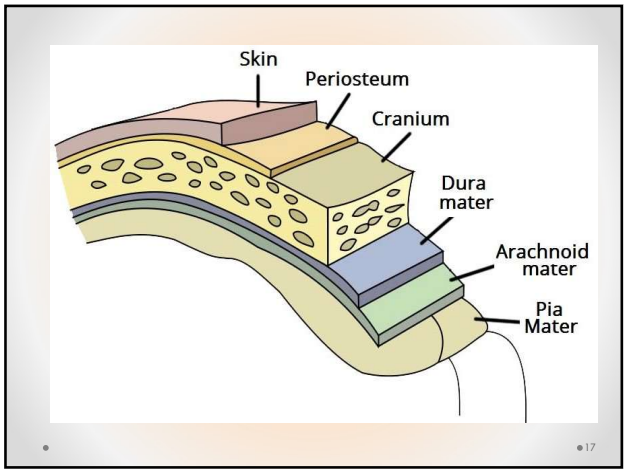
Skin
Periosteum
Cranium
Dura mater
Arachnoid mater
Pia Mater
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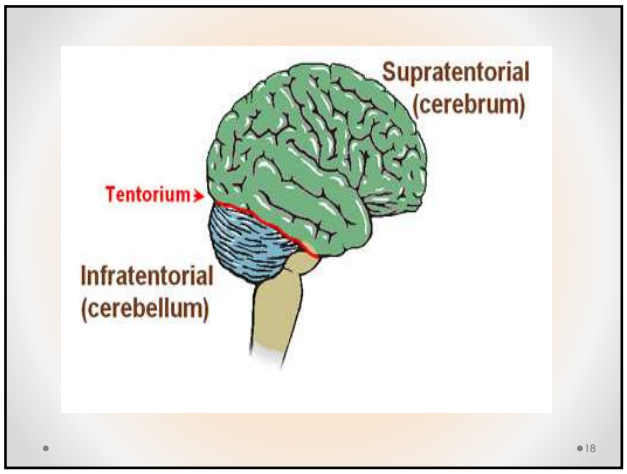
Supratentorial
(cerebrum)
Tentorium
Infratentorial
(cerebellum)
18

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Ventricular System

4 Ventricles:

- Two lateral
  - Anterior horns drain into interventricular foramina or foramen of Monro
- Third
  - Aqueduct of Sylvius
  - Cerebral aqueduct
- Fourth
  - Foramen of Magendie
    - drains into central canal of the spinal cord

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Lateral Ventricles

- **Lateral ventricles** divided into four segments:
  - Frontal horn
  - Body
  - Occipital
  - Temporal horn
- Largest of the CSF cavities
- Communicate with third ventricle through interventricular foramen

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Lateral Ventricles (cont'd)

- Atrium or trigone is site at which the following horns join
  - Anterior
  - Occipital
  - Temporal
- Body of lateral ventricle extends from foramen of Monro to trigone
- Corpus callosum forms roof; CSP forms medial wall
- Thalamus touches inferior lateral ventricular wall

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Relationships

- Roof of lateral ventricles
  - ♦Corpus callosum
- Medial wall
  - ♦Cavum septum pellucidi
- Inferior lateral walls
  - ♦Thalamus
- Superior walls
  - ♦Caudate nucleus

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Third Ventricle

- The lateral ventricles communicate with the third ventricle through paired foramina, individually referred to as the intraventricular foramen, or foramen of Monro
- Third ventricle is a narrow, irregularly shaped opening, which sits inferior and midline between the lateral ventricles
- Roof is formed by the corpus callosum
- The cerebral aqueduct, or aqueduct of Sylvius, connects the third and fourth ventricles and is the most narrow passage

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Fourth Ventricle

- Diamond-shaped and sits within the pons, or upper portion of the brain stem, between the cerebellar peduncles
- Anteriorly, the lower floor surface is formed by the medulla oblongata
- Roof is formed by the cerebellar vermis posteriorly

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Ventricular Variants

- Ventricular size varies with gestational age and the premature infant will normally have larger-appearing ventricles than the term infant
- Dilation of the lateral ventricles often begins in the occipital horns
- Minor asymmetry of the lateral ventricles is not uncommon, occurring in 20% to 40% of infants
- Left often larger than the right

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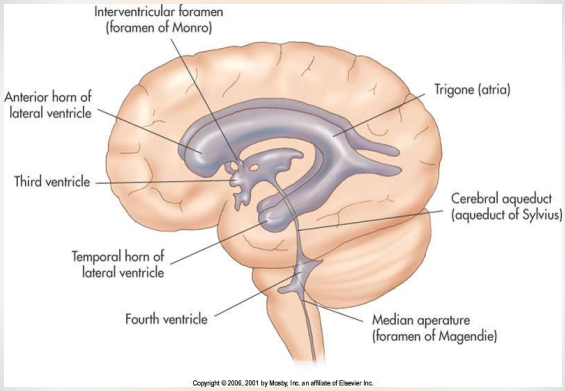

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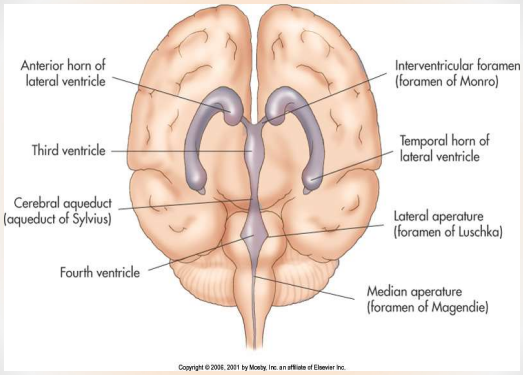

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Cerebrospinal Fluid (CSF)

- Do you remember what produces CSF???
- CSF surrounds and protects brain and spinal cord from physical impact
- Approximately 40% of CSF is formed by choroid plexuses of lateral, third, and fourth ventricles
  - remainder is produced by extracellular fluid movement from blood through brain and into ventricles
- Fluid may leave through the central foramen of Magendie or lateral foramen of Luschka into cisterna magna and basal subarachnoid cisterns

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CSF Pathway

- https://youtu.be/mpDxb7miJ1k

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Choroid Plexus

- Mass of special cells located in atrium of lateral ventricles
  - regulate intraventricular pressure by secretion or absorption of CSF
- Glomus (largest) is the tail of the choroid plexus and is a major site for bleeds
- Main and largest choroid is located in the atria (atriums) of the lateral ventricles and is responsible for most of the CSF production
- Prominent in preterm infants under 25 weeks of gestation, and often develops a normal
- appearance by 30 weeks

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Choroid Plexus (cont'd)

- Other structures that produce CSF in the ventricular system include the intracranial and spinal subarachnoid lining
- Additionally, the ventricles are lined with specialized ependyma that also produce cerebrospinal fluid (CSF)
  - along with the choroid plexus, regulate the normal intraventricular pressure by both secreting and absorbing CSF

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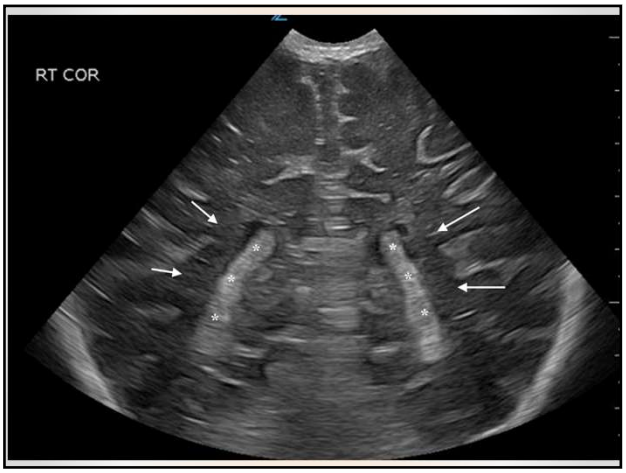

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Cavum Septum Pellucidum (CSP)

- Thin triangular space filled with CSF
- Lies between anterior horn of lateral ventricles
- Cavum vergae is found at the posterior tip of CSP
  - Closes at 24 weeks' gestation

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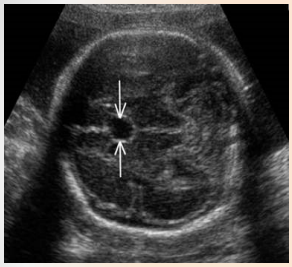

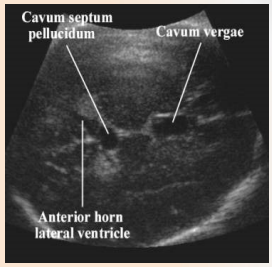

https://www.fetalultrasound.com/online/text/3-082.htm

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Cisterns

- Three apertures allow the CSF to leave the fourth ventricle, one centrally and two laterally, into the subarachnoid cisterns
- The lateral angles of the fourth ventricle form the foramina of Luschka which drain into the lateral cerebellopontine cisterns
- The inferior angle, the middle foramen of Magendie drains into the cerebellomedullary cistern, which is continuous with the cisterna magna and central canal of the spinal cord

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Cisterns (cont'd)

- The subarachnoid cisterns are the spaces at the base of the brain where the arachnoid becomes widely separated from the pia, giving rise to large cavities
- The cisterna magna is one of the largest of these subarachnoid cisterns and is consistently seen with ultrasound, appearing anechoic and located in the posterior fossa between the medulla oblongata, cerebellar hemispheres, and occipital bone

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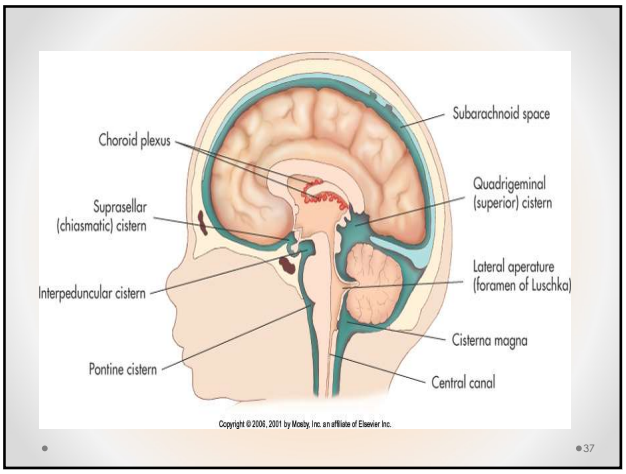

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Cerebrum

- Cerebral Hemispheres
  - Two, connected by corpus callosum
  - Separated by a longitudinal fissure into which projects the falx cerebri
- Consists of the grey (or gray) and white matter
- Outermost portion of the cerebrum is the cerebral cortex (composed of grey matter).
- White matter is located at the innermost portion of the cerebrum
  - largest and densest bundle of white matter is the corpus callosum

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Cerebrum (cont'd)

- Gyri are convolution on the surface of the brain caused by infolding of cortex
- Sulcus are grooves or depressions on surface of brain separating gyri
  - Divides hemispheres into frontal, parietal, occipital, and temporal lobes

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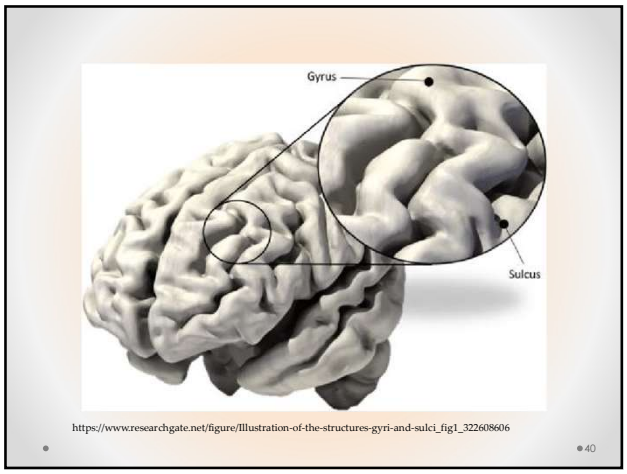
Gyrus
Sulcus
https://www.researchgate.net/figure/Illustration-of-the-structures-gyri-and-sulci_fig1_322608606
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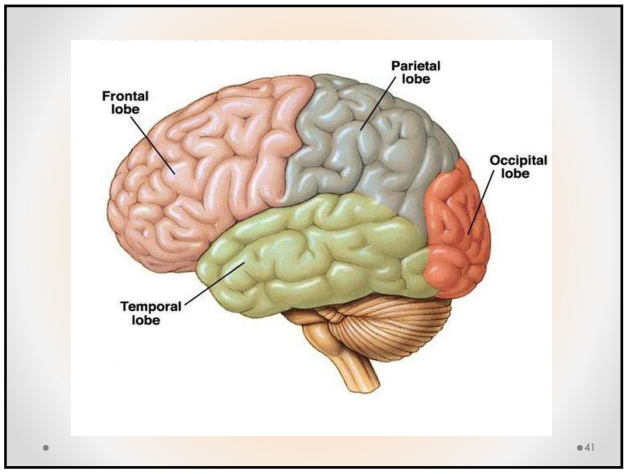
Frontal lobe
Parietal lobe
Occipital lobe
Temporal lobe
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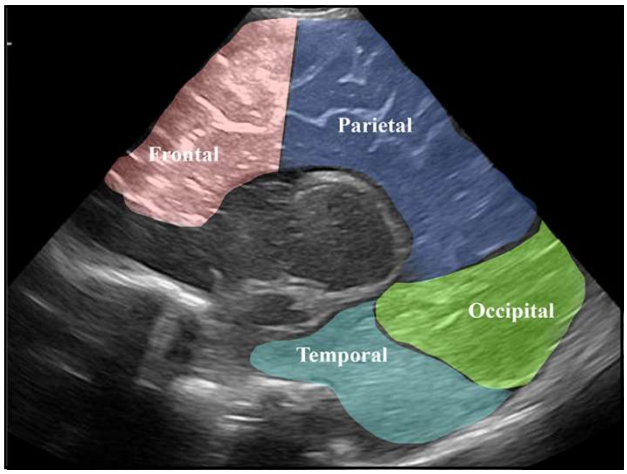
Frontal
Parietal
Occipital
Temporal

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Lobes

- Frontal lobe responsible for:
  - Speech
  - Emotions
  - Personality
  - Morality
  - Intellect
  - Judgement
  - Reasoning
  - memory
- Occipital lobe responsible for:
  - Vision

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Lobes (cont'd)

- Parietal lobe responsible for:
  - Somesthetic
  - Pain
  - Temperature
  - Spatial ability
- Temporal lobe responsible for:
  - Auditory
  - Olfactory

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Cerebrum (cont'd)

- Interhemispheric fissures is an area in which the falx cerebri sits and separates two cerebral hemispheres
- Sylvian fissures are located along lateral aspect of brain where MCA is located
- Quadrigeminal fissure located posterior and inferior to cavum vergae
- Vein of Galen also posterior

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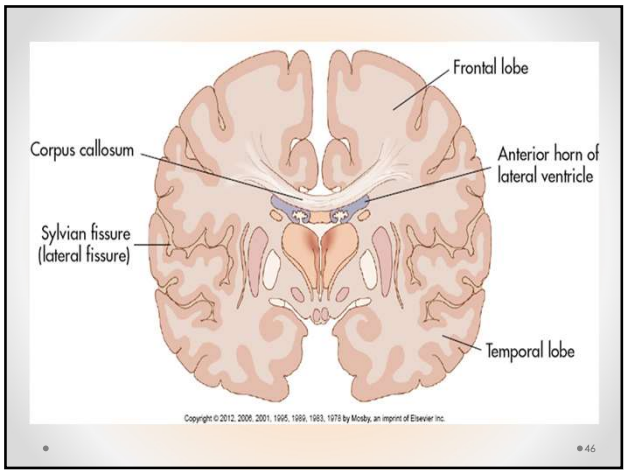

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Corpus Callosum

- Mass of white matter that connects the two cerebral hemispheres
- Forms the roof of the lateral ventricles
- Sits on top of CSP
- Composed of four parts:
  - Rostrum
  - Genu
  - Body
  - Splenium

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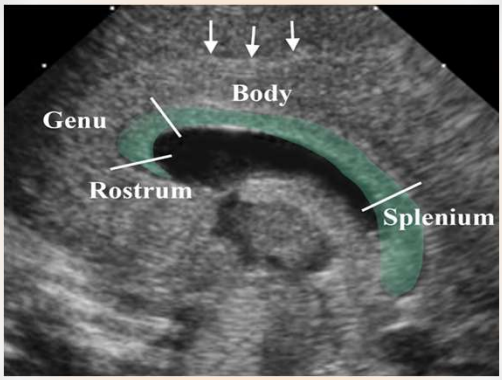

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Basal Ganglia

- Collection of gray matter than includes caudate nucleus, lentiform nucleus, claustrum, and thalamus
  - Caudate nucleus and lentiform nucleus are the largest basal ganglia
    - relay stations between thalamus and cerebral cortex
- Caudate nucleus divided into head, body, and tail
  - Forms the lateral borders of the frontal horns of the lateral ventricles and lies *anterior* to the thalamus
  - Head of caudate nucleus, at the caudothalamic groove, is a common site for hemorrhage

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Basal Ganglia (cont'd)

- The germinal matrix includes periventricular tissue and the caudate nucleus
  - Located 1 cm above the caudate nucleus in the floor of the lateral ventricle, at the caudothalamic groove
  - Sweeps from the frontal horn posteriorly into the temporal horn
  - 90% of premature brain bleeds occur here and is made up of a highly vascular bed of delicate blood vessels, especially in infants under 34 weeks of gestation

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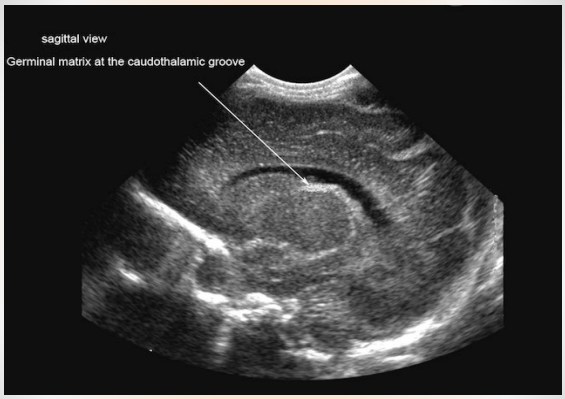

https://pocusneo.org/pocus-hus-module/pages/matu_germ_matrx_inv_11.html

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Thalamus

- Consists of two ovoid, egg-shaped brain structures situated on either side of the third ventricle, superior to the brainstem
- Borders the third ventricle and connects through the middle of the third ventricle by the massa intermedia, which is composed of grey matter and exists in most neonatal brains
- The hypothalamus forms the floor of the third ventricle and the pituitary gland is connected to the hypothalamus by the infundibulum

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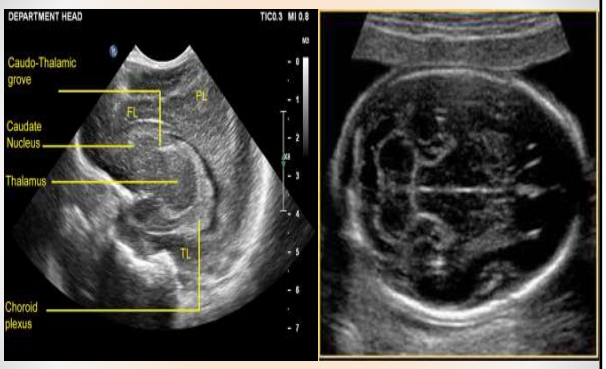

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Brain Stem

- Part of brain connecting forebrain and spinal cord
- Consists of:
  - Midbrain
  - Pons
  - Medulla oblongata

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Midbrain

- Connects forebrain to hindbrain
- Consists of two halves
  - Cerebral peduncles
- Cerebral aqueduct
  - Narrow cavity of midbrain that connects third and fourth ventricle

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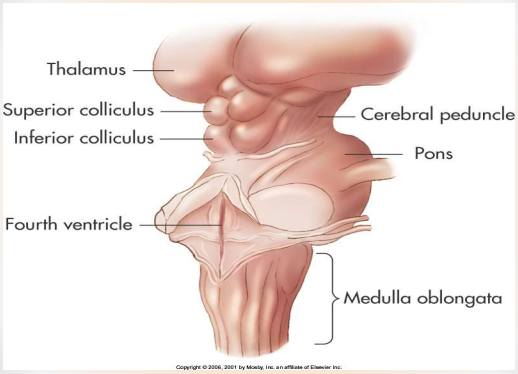

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Pons

- Found on anterior surface of cerebellum:
  - Below midbrain
  - Above medulla oblongata

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Medulla Oblongata

- Extends from pons to foramen magnum where it continues as spinal cord
- Contains fiber tracts between brain and spinal cord
- Regulates important activities of the body such as:
  - Heart rate
  - Respiration
  - Blood pressure

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Cerebellum

- Composed of two hemispheres that have appearance of cauliflower connected by a vermis
- Lies in posterior cranial fossa under tentorium cerebelli
- Three pairs of nerve tracts, cerebellar peduncles, connect cerebellum to brain stem
- Responsible for skeletal muscle movement

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Cerebrovascular System

- Consists of internal cerebral arteries, vertebral arteries, and circle of Willis
- Middle cerebral artery (branch of the internal carotid artery) and circle of Willis are often evaluated with Doppler ultrasound in determining cerebral blood flow patterns

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Sonographic Evaluation of the Neonatal Brain

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Indications

- Cranial abnormality seen on prenatal sonogram
- Increased HC with or without increasing intracranial pressure
- Acquired or congenital inflammatory disease
- Prematurity
- History of birth trauma or surgery
- Genetic syndromes or malformations
- Low Apgar score

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APGAR score

- Quick test performed on a baby at 1 and 5 minutes after birth
  - Score of 0-10
- The 1-minute score determines how well the baby tolerated the birthing process (OB APGAR). The 5-minute score tells the doctor how well the baby is doing outside the womb (neonatal APGAR).
- Consists of:
  - Breathing effort
  - Heart rate
  - Muscle tone
  - Reflexes
  - Skin color
  - https://youtu.be/GsAag-KwkB4

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Indications (cont'd)

- Any of the following diagnoses:
  - Hypoxia
  - Hypertension
  - Hypercapnia
  - Hypernaturemia
  - Acidosis
  - Pneumothorax
  - Asphyxia
  - Apnea
  - Seizures
  - Coagulation defects
  - Patent ductus arteriosus

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Supratentorial

- Visualizes:
  - Both cerebral hemispheres
  - Basal ganglia
  - Lateral and third ventricles
  - Interhemispheric fissure
  - Subarachnoid space surrounding hemispheres

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Infratentorial

- Visualizes:
  - Cerebellum
  - Brain stem
  - Fourth ventricle
  - Basal cisterns

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Neonatal Head Examination Protocol

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Handle with Care

- Asepsis and infection control
  - Handwashing
  - If being performed in a nursery or NICU – may need to have a gown and mask
  - Clean transducers, cables and equipment ***
  - May require sterile gel
  - Isolation precautions if needed

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Handle with Care (cont'd):

- If newborn is under an oxygen hood, have the nurse remove and hold the hose close to the nose
- Want to be proficient in the exam to reduce the scanning time
- Light pressure on the fontanelle
  - Increased pressure can affect respiratory rate or create seizures
- Be careful of IV lines

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Examination Preparation

- For the premature or sick infant, most neurosonography examinations are performed portable in the NICU
- Always consult with the infant's nurse before beginning the exam
- Key concerns are keeping the premature infant safe and warm
  - Use only a small amount of gel while scanning
  - Beware of multiple wires and tubes or monitors
  - Practice good infection control techniques

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Examination Preparation

- The exam should be done with the patient in the supine position, though you may encounter patients in various positions depending on their care
  - If patient is in lateral decubitus, the exam can still be done
- Use low gray-scale contrast and multiple focal zones throughout the depth of the image to help optimize the lateral resolution of brain parenchyma to detect any subtle changes

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Transducer Selection

- Transducer
  - Curved array
  - Small, linear sector
  - 7-10 MHz
  - May need lower frequencies (5-7 MHz) for older infants or infants with thick hair
  - 3-5 MHz may be needed to visualize deeper structures
- Coronal, modified coronal, sagittal, and parasagittal planes are used to study:
  - Supratentorial compartment
  - Infratentorial compartment

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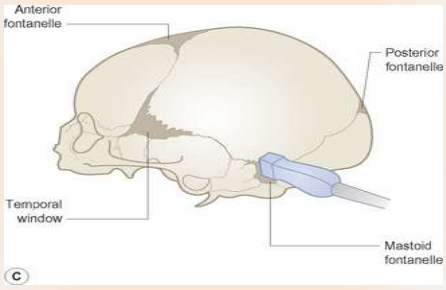
Scanning Approaches



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Main Goals…

- Ventricle size and configuration
- Corpus callosum location/presence
- Appearance of caudothalamic groove
- Appearance of cerebellum, cerebellar vermis, and 4th ventricle

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Coronal Plane

- Vertex of skull is at top of screen and left side of brain is to right of the image
- Transducer is placed on anterior fontanelle with scanning plane following the coronal suture
- Must be centered in coronal suture to reduce bone interference

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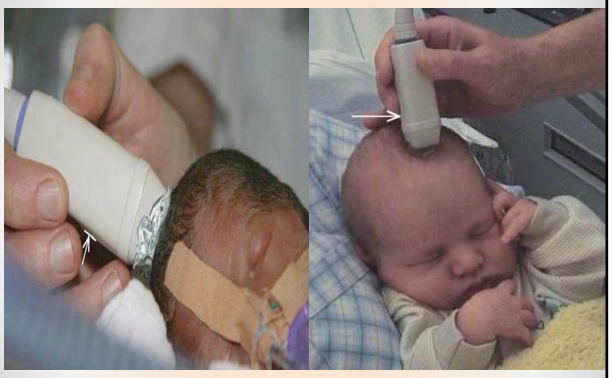

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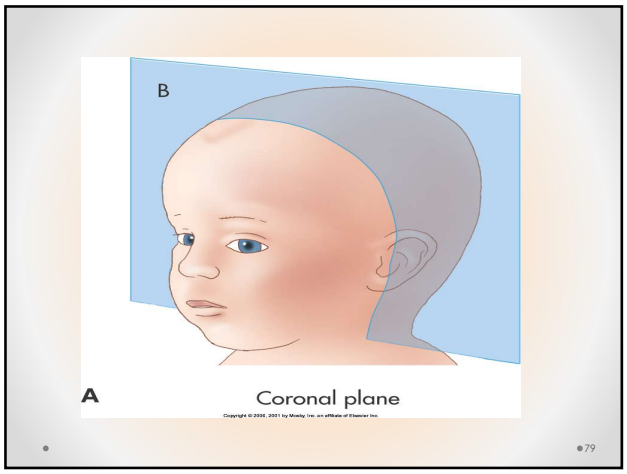

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Coronal and Modified Coronal Planes

- **Coronal**
  - Anterior:
    - Orbits
    - Anterior horns of lateral ventricles
    - Frontal lobe of cerebral cortex
    - Interhemispheric fissure
  - Middle:
    - Frontal horns of lateral ventricles
    - CSP
    - 3rd vent
    - Corpus callosum
    - Thalami
    - Interhemispheric fissure
  - Posterior:
    - Ambient wings and cisterna magnum
    - Tentorium and cisterna magnum
    - Choroid
    - Sylvian fissures
    - Pons/medulla oblongata
    - Tentorium
    - Cerebellum
    - Cisterna Magna
    - Glomus of choroid plexus
    - Atria of lateral ventricles
    - Periventricular blush
    - Occipital lobe of cerebrum

80

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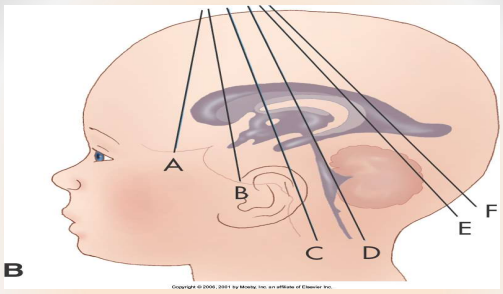

Coronal scan planes as the transducer is angled from the anterior to posterior skull as described in the text. *A* through *F* indicate the different scanning planes. *A* is the most anterior, and *F* is the most posterior.

81

81

(Next two slides)

- Normal protocol for coronal images beginning with transducer angled toward anterior skull
  - A & B
- Angled to midcoronal section
  - C,D,E,& F
- Angled toward posterior occipital area of skull
  - G & H

82

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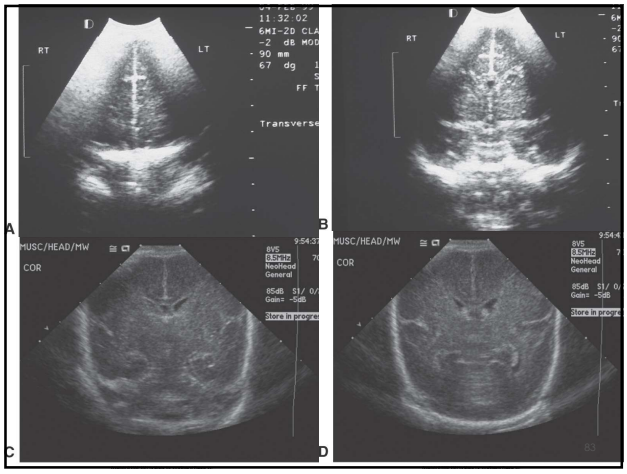
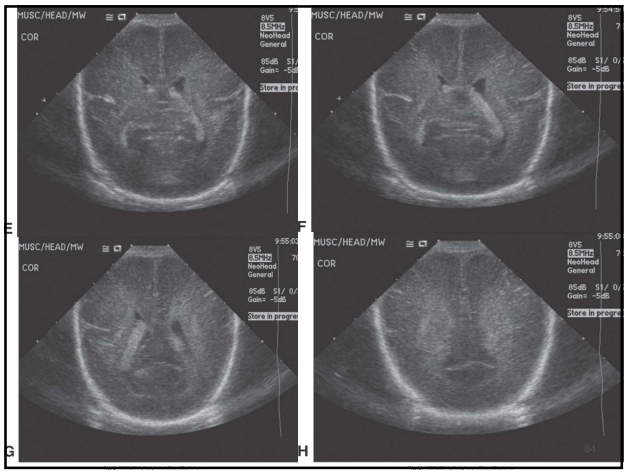


83



84

Modified Coronal Studies of Ventricles and Posterior Fossa

- Demonstrates body of lateral ventricles, third ventricle, and posterior fossa
- To obtain this view
  - Transducer is positioned over the anterior fontanelle with an angle of approximately 30 to 40 degrees between scanning plane and surface of fontanelle
- Tentorium, cerebellar vermis, fourth ventricle, cerebellar hemispheres, and cisterna magna can be seen

85

85

Coronal Studies Through Posterior Fontanelle

- Used as an alternative window to image choroid plexus and lateral ventricles
  - If anatomic structures are difficult to image because of overlapping bones in the area of the fontanelle

86

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Sagittal

- Steps should be done separately for each side of the brain
- **Midline**
  - ➢CSP
  - ➢ Corpus callosum
  - ➢ 3rd vent
  - ➢Foramen of Monro
  - ➢Aqueduct of Sylvius
  - ➢Fourth ventricle
  - ➢Cerebellum (tentorium)
  - ➢Cisterna magna
  - ➢Thalamus
  - ➢Caudothalamic groove (notch)
  - ➢Lateral ventricle: anterior, body, and occipital (temporal if hydrocephalic)

87

87

Parasagittal

- Obtained by angling transducer to right or left of midline
- Three parasagittal studies should be performed:
  1. Should be close to midline to visualize caudate nuclei in detail
     *subependymal hemorrhages begin in germinal matrix
     - Caudothalamic groove
     - Caudate nucleus
     - Choroid plexus
     - Thalamus
  2. Made slightly lateral to first image and includes entire ventricular cavity
     - Entire lateral ventricle
     - Glomus of choroid plexus
  3. Images white matter located lateral to lateral ventricles
     *useful in studying intraparenchymal hemorrhages, porencephaly, and periventricular leukomalacia
     - Parietal and temporal lobes
     - Sylvian fissure

88

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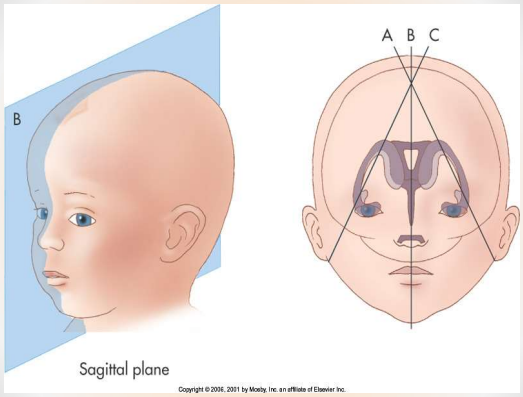

89

89

(Next two slides)

- Normal protocol for sagittal images beginning with transducer perpendicular to skull
  - A
- To right
  - B, C, D, and E
- back to the midline
  - F
- To left
  - G and H

90

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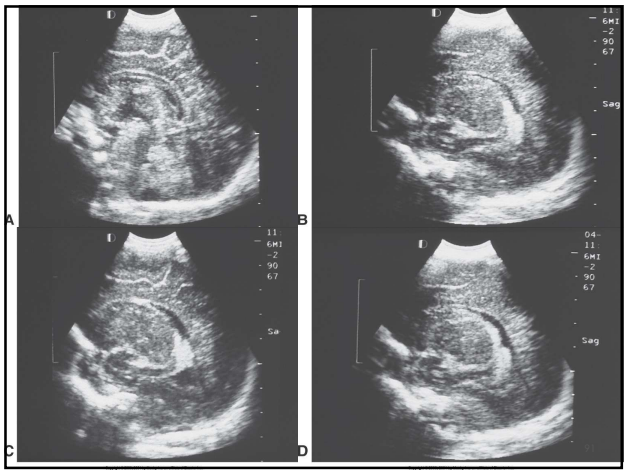

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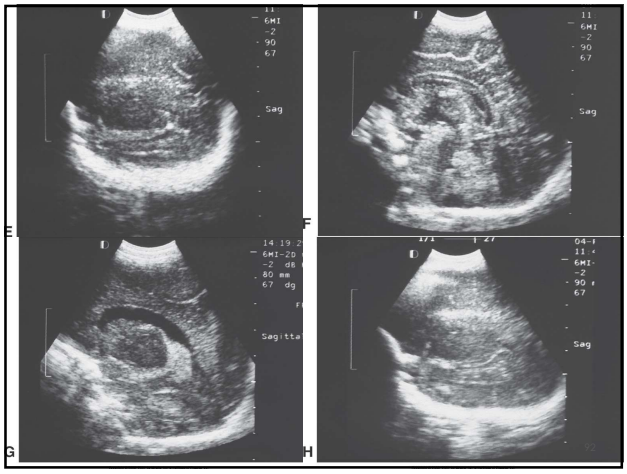
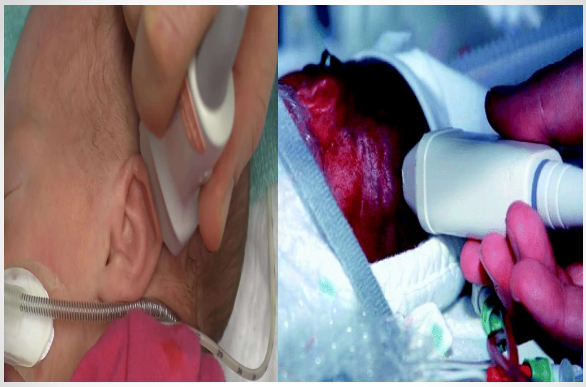


92

Additional Views

- Mastoid fontanelle
  - Posterior to ear
  - Detects anomalies of the third and fourth ventricles and cerebellum
  - Circle of Willis
- Posterior fontanelle
  - Looks at body, temporal, and occipital horns of lateral ventricles
  - Detailed image of the choroid plexus
  - Occipital horn
- Sphenoid fontanelle (temporal window)
  - Anterior horn
  - Frontal horn

93



https://link.springer.com/chapter/10.1007/978-3-319-77815-0_14

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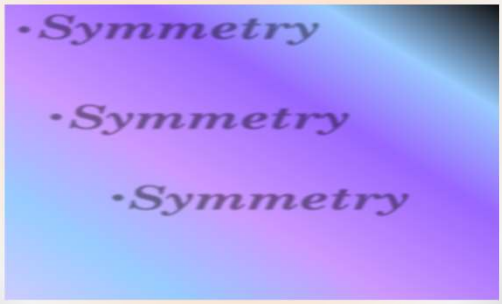
- https://youtu.be/E0YCpIOAr00



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Doppler Measurements

- Hemodynamic changes may be recorded by color and spectral Doppler
- Can identify infants with elevated intracranial pressures as well as evaluation of:
  - Decreased blood flow
  - Vascular abnormalities
  - Cerebral edema
  - Hydrocephalus
  - Intracranial tumors
  - Near-field structures

96

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Hemorrhagic Pathology

97

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Ventriculomegaly

- Enlargement of the ventricles (unilat. or bilat.) without increased head circumference

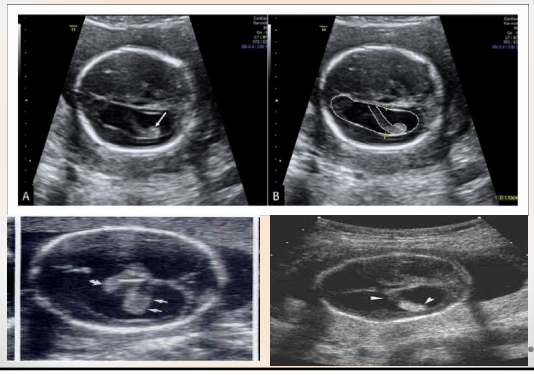
Types:
- Communicating
- Non-communicating
- Result of cerebral atrophy

Sonographic Findings:
- Ventricles greater than normal size- first seen in trigone and occipital horn areas
- Visualization of 3rd/4th ventricle
- "dangling" choroid plexus
- Thinned brain mantle (if caused by cerebral atrophy)

98

98

"Dangling" choroid plexus



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Hydrocephalus

- Caused by a variety of conditions leading to the obstruction, overproduction or decreased absorption of CSF
- May be acquired or congenital
  - Acquired- results from CSF obstruction from an intracranial hemorrhage (ICH), also known as post-hemorrhagic hydrocephalus (PHH) when severe dilation occurs, or after the loss of deep white matter in PVL
  - Congenital- occurs before birth and may be due to structural malformations or congenital brain infections.
- Earlier it occurs, the greater enlargement of head
- Types:
  - Communicating
  - Non-communicating

100

100

Aqueductal Stenosis

- *Most common cause of hydrocephalus
  - Aqueduct of Sylvius is narrowed or replaced by multiple small channels with blind ends
  - Can be diagnosed when an infant is born with widening of lateral and third ventricles and a normal-size fourth ventricle
  - If the hydrocephalus is very large, the posterior fossa is smaller than usual, and the cerebellum is displaced toward the occipital bone with the disappearance of the cisterna magna

101

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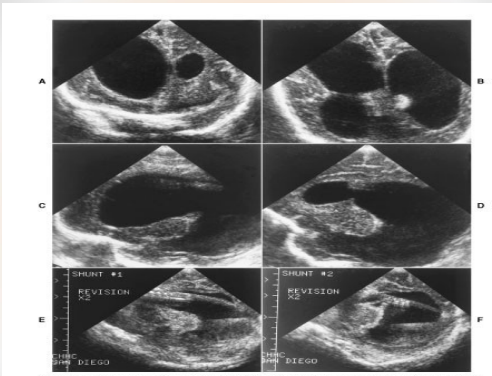

Figure 16-29 **A** through **D,** A 4-month-old infant with hydrocephalus shows dilation of the lateral ventricles. **E** and **F,** Follow-up study of the infant shows the shunt tubing in place for drainage of the hydrocephalus. Ultrasound is very useful in following the shunt placement, as well as monitoring the drainage of the dilated ventricle.

102

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Communicating Hydrocephalus

- CSF pathways are open but there is decreased absorption of CSF
- Entire ventricular system becomes uniformly distended

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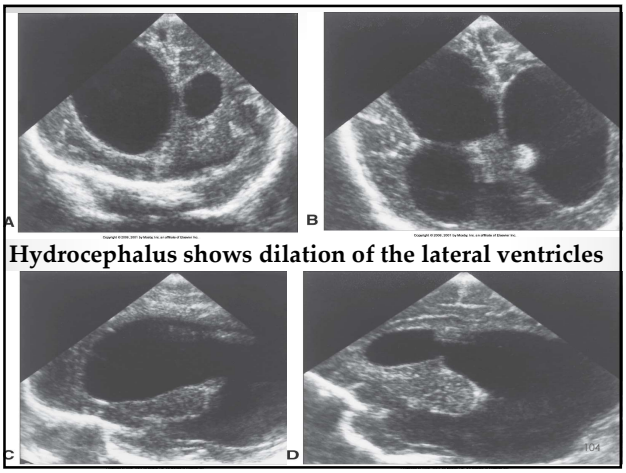

Hydrocephalus shows dilation of the lateral ventricles

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Increased Intracranial Pressure (ICP)

- Cause of, or result of, brain injury
- ICP restricts cerebral blood flow and is a serious medical condition
- The drainage of CSF, via a ventricular shunt or reservoir, plays a central role in treatment
- Hemodynamic changes may be recorded by spectral Doppler and utilized to identify infants with elevated ICP
  - A tracing from the pericallosal artery is obtained from the anterior fontanel
    - If a reversal of flow exists, this is an indication of ICP and fontanel pressure is not recommended
    - If no reversal is detected, then ok to apply pressure to the anterior fontanel

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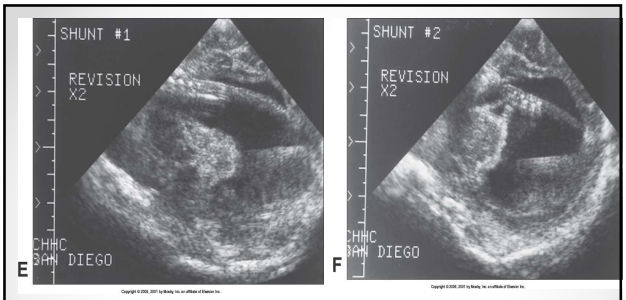

Follow-up study of the infant shows the shunt tubing in place for drainage of the hydrocephalus. Ultrasound is very useful in following the shunt placement and monitoring the drainage of the dilated ventricle.

106

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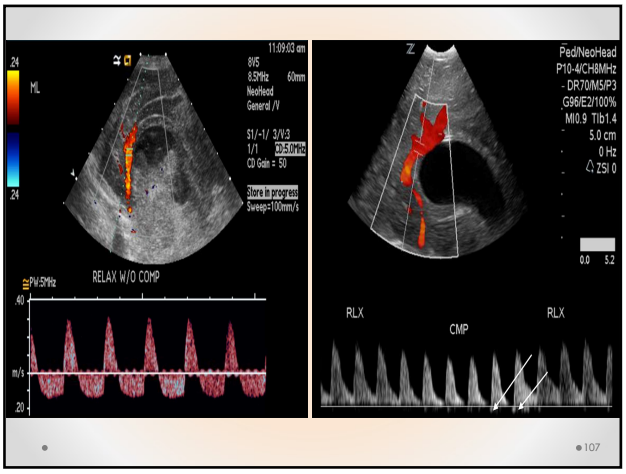

107

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Ventricular Measurements

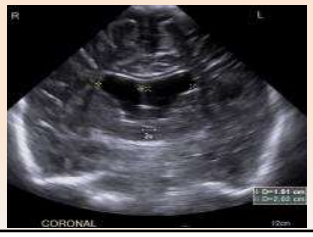
- The most reproducible ventricular biometric measurements are:
  - ventricular index (VI)
  - anterior horn width (AHW)
  - thalamo -occipital distance (TOD)

108

108

Ventricular Measurements (cont'd)

- Ventricular index (VI) measurements are taken at the level of the third ventricle in a coronal view, with VI measured at the widest point to the falx



109

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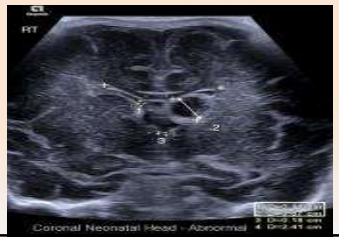
Ventricular Measurements (cont'd)

- Anterior horn width (AHW) is also measured from the same coronal view as the ventricular index. Measured across the widest point of the ventricle at a diagonal.



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Ventricular Measurements (cont'd)

- From this same coronal view at the level of the third ventricle, the frontal temporal horn ratio (FTHR) may be calculated

  bilateral frontal horn dimension + bioccipital horn dimension/ 2 x biparietal calvarial dimension

- The bifrontal horn dimension is measured at the greatest width across both frontal horns, the biparietal calvarium is measured from the greatest width of one side of the calvarium to the other, and the biparietal occipital horn is measured at the greatest transverse dimension of the occipital horn anterior to the brainstem

111

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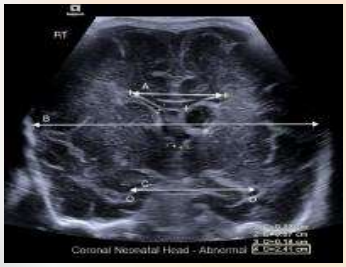
Ventricular Measurements (cont'd)



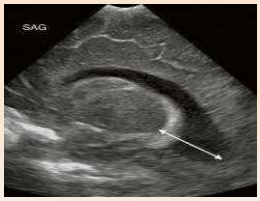
Frontal temporal horn ratio (FTHR)

112

112

Ventricular Measurements (cont'd)

- The thalamo-occipital distance (TOD) is taken from a parasagittal view and is measured from the outermost part of the occipital horn to the junction of the choroid with the outermost part of the thalamus



113

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Extra-axial Fluid

- It is hypothesized that immature arachnoid granulations in infancy may cause CSF to accumulate in the subarachnoid space
- The arachnoid granulations only form at birth and develop until 18 months
- Before birth lymphatic pathways are utilized, this drainage also continues throughout the neonatal period

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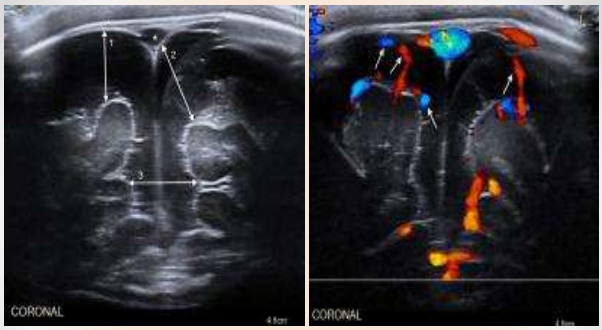

If cortical vessels are seen passing through the superficial fluid, also known as the cerebral cortical vein sign, it suggests the collection is subarachnoid.

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Intracranial Hemorrhage (ICH)

- Subependymal-intraventricular hemorrhages (SEHs-IVHs) are the most common hemorrhagic lesions in preterm infants
- Caused by capillary bleeding in the germinal matrix, because of this, may also be called germinal matrix intraventricular hemorrhages (GM-IVH)
- Affect 40-70% of infants who are born at less than 34 weeks
- *Most frequent location is at the caudothalamic groove
- Sonographic appearance and location depends on the grade and age of the
- hemorrhage/clot

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Intracranial Hemorrhage (ICH)

- Sonographic findings:
  - Acute hemorrhage will appear more echogenic than chronic
  - Subependymal hemorrhage: Usually seen at thalamic-caudate notch as very echogenic lesion pushing up floor and external wall of lateral ventricle with partial obliteration of ventricular cavity.
  - Can extend by continuous bleeding and perforate ventricular wall with partial or total flooding of ventricular system

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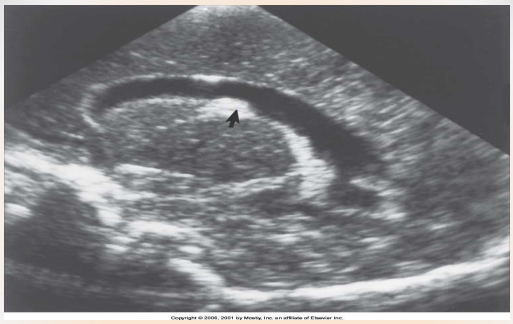

Small subependymal bleed *(arrow)*

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Grades of SHE-IVH

- Grade I: SEH or IVH without ventricular enlargement
- Grade II: SEH or IVH with minimal ventricular enlargement
- Grade III: SEH or IVH with moderate or large ventricular enlargement
- Grade IV: SEH or IVH with intraparenchymal hemorrhage

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Grades of SHE-IVH (cont'd)

- Ventricular size

Mild dilation:	8 to 10 mm
Moderate dilation:	11 to 14 mm
Severe dilation:	>14 mm

120

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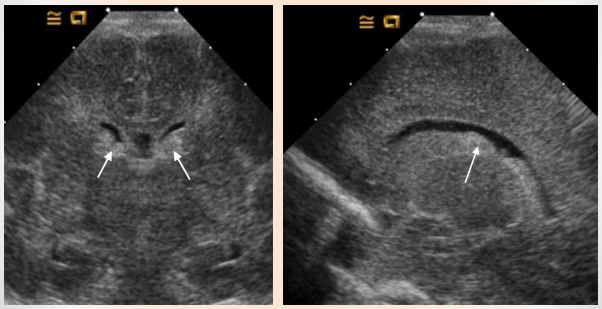
Grade I



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121

Grades II & III

- IVHs are not a sudden event; they usually expand slowly
- Typically, when a small GM-IVH progresses to a large IVH (usually during the first 4 postpartum days), the IVH are asymptomatic
- In some infants the GM-IVH extend very fast; sudden flooding and distention of the ventricles by hemorrhage is associated with the clinical symptoms of shock, seizures, hypoxemia, and a sudden decrease in the hematocrit

122

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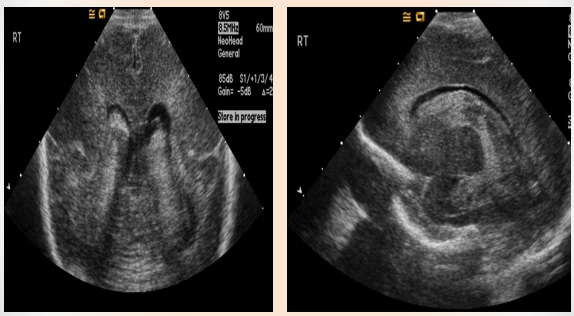
Grades II & III



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Grade IV

- Severe complication- indicates that brain parenchyma has been destroyed
- Primary infarction of periventricular and subcortical white matter with destruction of lateral wall of ventricle
- When necrotic tissue liquefies, IVH extends into necrotic areas

124

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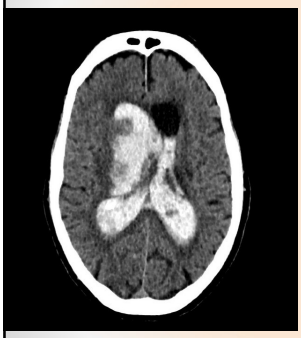
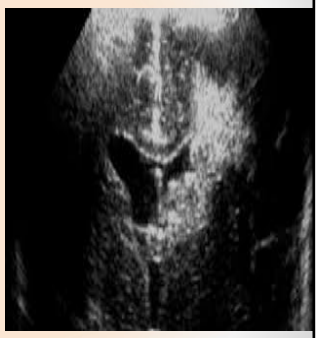
Grade IV





https://radiologyassistant.nl/pediatrics/spine/neonatal-brain-us
https://radiopaedia.org/articles/intraventricular-haemorrhage

125

125

Intraparenchymal Hemorrhages (IPHs)

- Complicate SEHs-IVHs in approximately 15% to 25% of infants
- Severe complication
  - Indicate the brain parenchyma has been destroyed
- Appear as very echogenic zones in white matter adjacent to lateral ventricles
- Echogenic areas in white matter may correspond to
  - IPHs
  - Hemorrhagic infarctions
  - Extensive periventricular leukomalacia

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Intracerebellar Hemorrhages

- Four categories:
  1. Primary intracerebellar hemorrhage
  2. Venous infarction
  3. Traumatic laceration resulting from occipital diastasis
  4. Extension to the cerebellum of a large SEH-IVH

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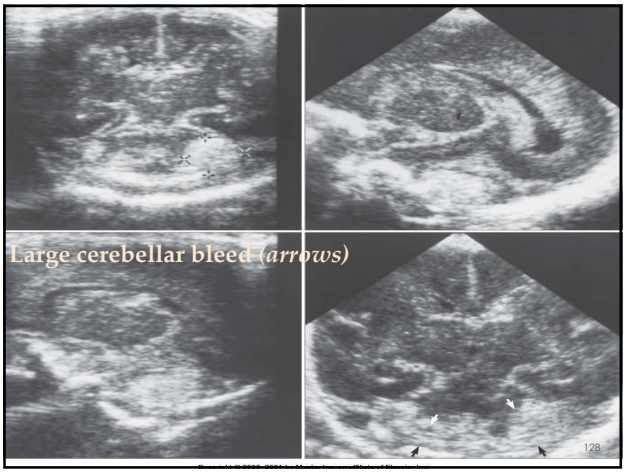

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Epidural Hemorrhages and Subdural Fluid Collections

- Better evaluated with CT
  - Lesions are located peripherally along surface of brain
- Subdural collections- appear as non-echogenic spaces between echogenic calvarium and cortex
- Epidural hemorrhages- echogenic formations located immediately underneath calvarium

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ECMO

- Neonatal ultrasound is primarily used to monitor hemorrhage in the brain tissue of infants on extracorporeal membrane oxygenation (ECMO)
- Used for pulmonary and circulatory support in many neonatal conditions to allow additional time for the lungs to develop

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Ischemic-Hypoxic Injury Lesions

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Ischemic-Hypoxic Lesions

- Ischemic: Hypoxic cerebral injury frequent complication of sick newborn infants
- Hypoxia: Lack of adequate oxygen to brain
- Ischemia: Lack of adequate blood flow to brain
- Can result from a variety of insults such as:
  - Respiratory failure
  - congenital heart disease
  - sepsis

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Periventricular Leukomalacia (PVL)

- Aka. multifocal white matter necrosis
- *Most frequent ischemic lesion in the immature brain
- Sonographic findings:
  - Areas of increased echogenicity in subcortical and deep white matter in basal ganglia
  - When necrosis, results in echolucencies (appears as cysts)
  - Results in abnormal neurologic development (cerebral palsy)
  - Results from an infectious process during pregnancy

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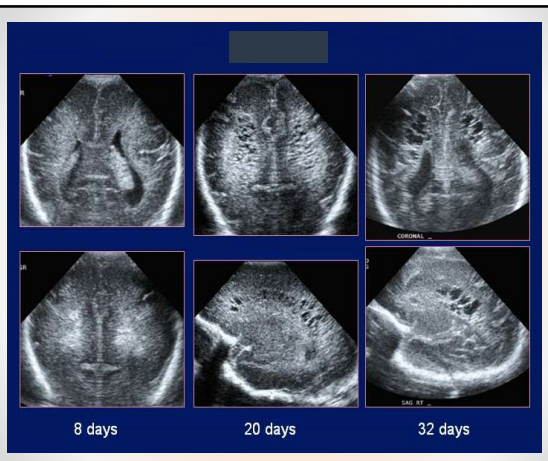

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Focal Brain Necrosis

- Necrotic lesions occur within distribution of large arteries
- Complication is present in term and preterm infants
  - Infrequent under 30 weeks' gestational age
- Causes:
  - Vascular maldevelopment
  - Asphyxia or hypoxia
  - Embolism from the placenta
  - Infectious diseases
  - Thromboembolism secondary to disseminated intravascular coagulation
  - Polycythemia

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Developmental Issues of the Brain

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137

Neural Tube Defects

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Chiari Malformations

- Congenital anomaly associated with spina bifida
  - Cerebellum and brain stem are pulled toward spinal cord
  - Secondary hydrocephalus develops
- Characterized by the following:
  - Displacement of fourth ventricle and upper medulla into cervical canal
  - Displacement of inferior part of cerebellum through foramen magnum
  - Defects in calvarium and spinal column

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Chiari Malformations (cont'd)

- Types of Chiari malformations:
  1. Type I
     - Found in adulthood
     - Caudal displacement of cerebellum without displacement of 4th ventricle or medulla
  2. Type II
     - *Most common form, aka. Arnold-Chiari malformation
     - Of major clinical importance because of association with myelomeningoceles or myeloceles
     - Requires surgery
  3. Type III
     - Rare, associated with encephalomeningocele containing cerebellum, fourth ventricle, and medulla
     - Fatal, diagnosed at birth
  4. Type IV
     - Cerebellum not fully formed, no displacement
     - Most don't survive past infancy

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Chiari Malformations (cont'd)

- Sonographic findings:
  - Hydrocephalus present in 90% of cases
  - Small, dysplastic, "banana-shaped" cerebellum
  - Absence of cisterna magna with displacement occurring through foramen magnum
  - Pons and medulla are inferiorly displaced
  - Fourth ventricle is elongated
  - Third ventricle may be slightly dilated and dysplastic
  - Frontal horns of lateral ventricles small, posterior horns enlarged- "bat wing" sign
  - Posterior horns of lateral ventricles are quite enlarged
  - Inward shape of frontal bones (frontal bossing)- "lemon-shaped" skull

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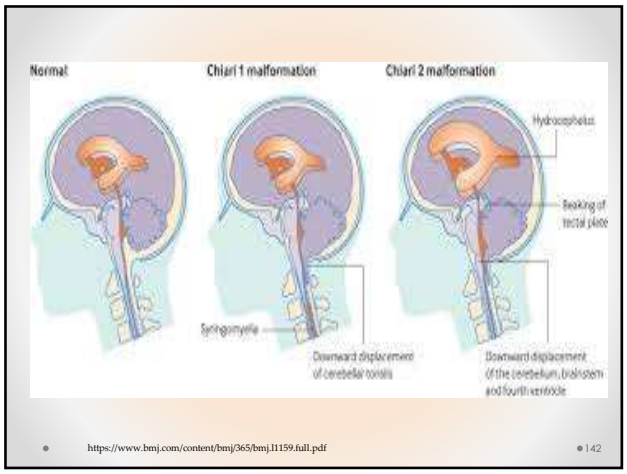
Normal
Chiari 1 malformation
Chiari 2 malformation
Hydrocephalus
Beaking of tectal plate
Syringomyelia
Downward displacement of cerebellar tonsils
Downward displacement of the cerebellum, brainstem and fourth ventricle
https://www.bmj.com/content/bmj/365/bmj.l1159.full.pdf
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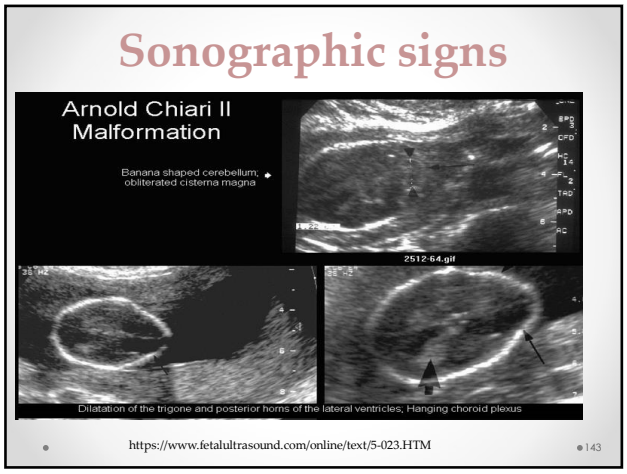
Sonographic signs
Arnold Chiari II Malformation
Banana shaped cerebellum, obliterated cisterna magna
2512-64.gif
Dilatation of the trigone and posterior horns of the lateral ventricles; Hanging choroid plexus
https://www.fetalultrasound.com/online/text/5-023.HTM
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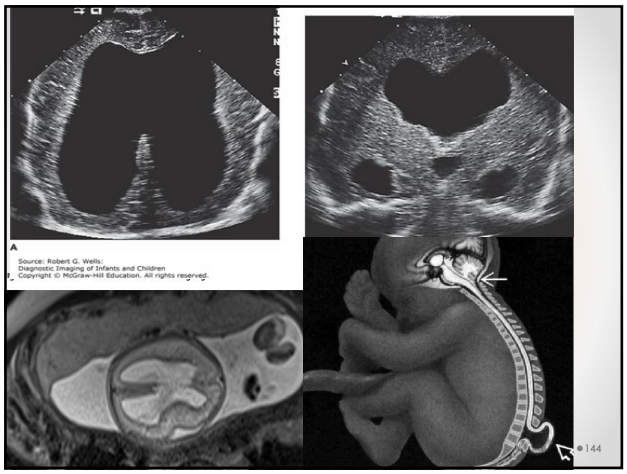
Source: Robert G. Wells: Diagnostic Imaging of Infants and Children
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Agenesis of the Corpus Callosum

- Condition in which fibers of corpus callosum cross from side to side on a glial sling
- Agenesis may occur as an isolated anomaly without any clinical effect
- Corpus callosum is absent in severe holoprosencephaly
- May be associated with Arnold-Chiari malformation and hydrocephalus
- Sonographic findings:
  - "sunburst" appearance of gyri
  - Colpocephaly
  - "batwing" appearance of ventricles

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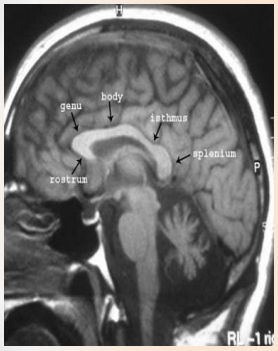

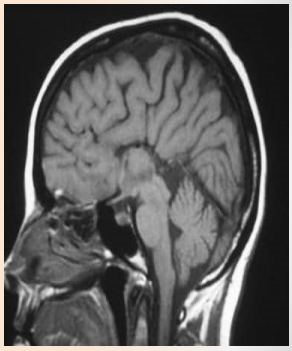

https://emedicine.medscape.com/article/407730-overview?form=fpf

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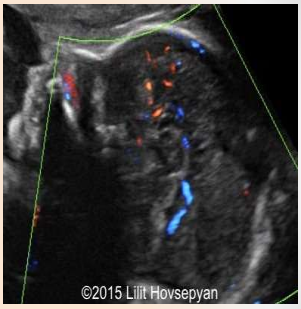
https://youtu.be/ePMLH5lQw1I?si=TkIsv-exK3ByP-Kc



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Dandy-Walker Malformation (DWM)

- Congenital anomaly in which a huge fourth ventricle cyst occupies area where cerebellum usually lies
  - Secondary dilation of third and lateral ventricles
- Fourth ventricle is enlarged
- Posterior fossa is enlarged with sinuses displaced upward

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DWM (cont'd)

- May be associated with the following malformations:
  - Hydrocephalus
  - Agenesis of the corpus callosum, infundibular hamartomas, or brain stem lipomas
- Typical malformation is characterized by:
  - Absence of the cerebellar vermis
  - Cystic changes in the fourth ventricle with development of a large cyst in posterior fossa (Dandy-Walker cyst)
  - Hydrocephalus

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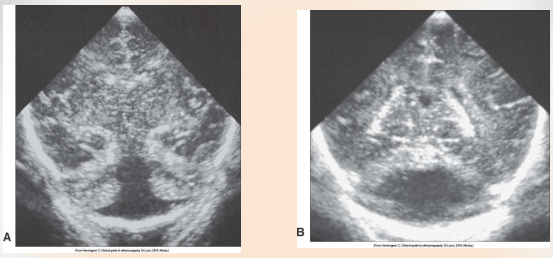

Sonographic evaluation showed posterior fossa cyst and splaying in cerebellar hemispheres as noted in coronal images. No hydrocephalus was identified.

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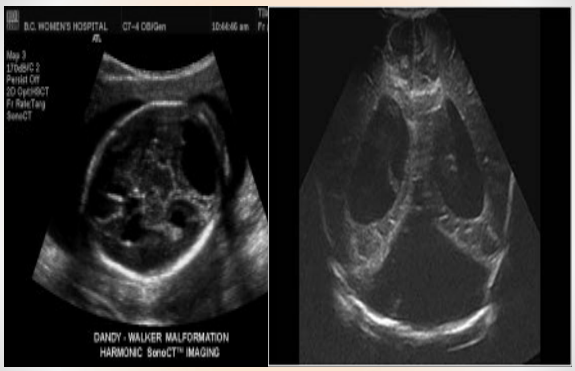

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Holoprosencephaly

- Characterized by a grossly abnormal brain with one large, central ventricle
- Caused by disturbances in process of ventral induction
- Sonographic findings:
  - Single cerebrum with single ventricular cavity
  - Absence of corpus callosum and frontal horns
  - Thin membrane arising from roof of third ventricle
    - May extend posteriorly forming a supratentorial cyst

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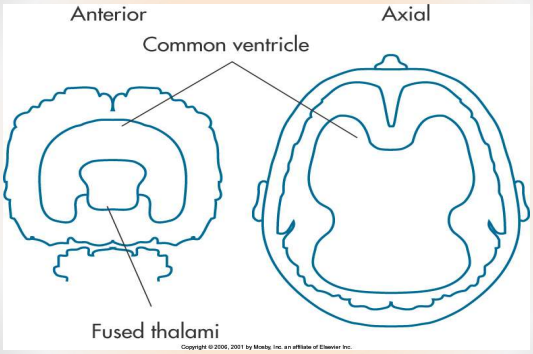

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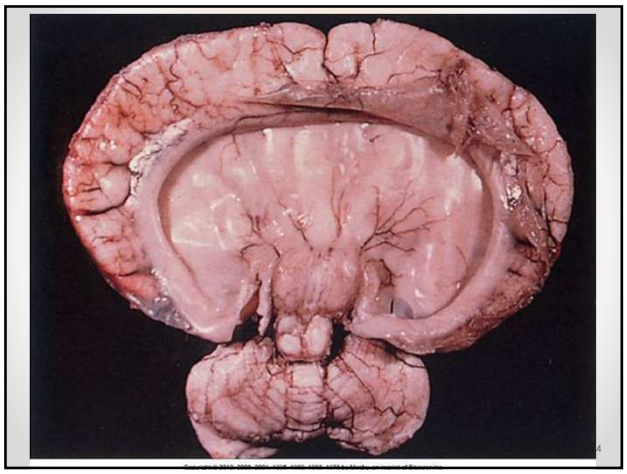

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Alobar Holoprosencephaly

- Most severe
- Multiple facial anomalies
  - Thalami are fused
  - No falx, corpus callosum or interhemispheric fissure present
  - Third ventricle is absent

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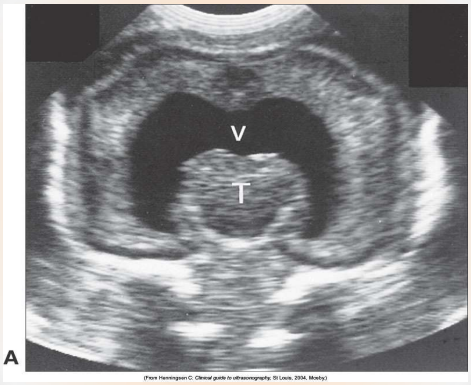

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Semilobar Holoprosencephaly

- Single ventricle with pieces of falx and interhemispheric fissure in posterior segment
- Possible Anomalies
  - Separate occipital and temporal horns
  - Splenium of corpus callosum is formed
  - Thalami are partially separated
  - Third ventricle is rudimentary
  - Mild facial anomalies

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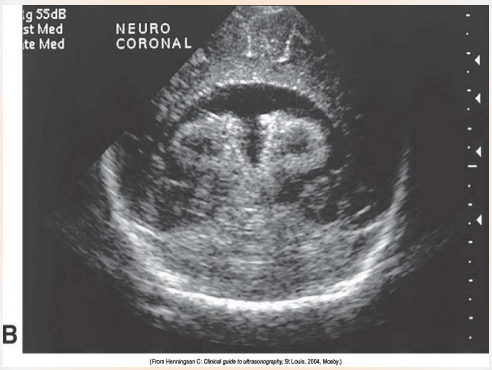

(From Henningsen C: Clinical guide to ultrasonography, St Louis, 2004, Mosby.)

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Lobar Holoprosencephaly

- Least severe form
  - Complete separation of hemispheres with development of falx and interhemispheric fissure
  - May be fusion of frontal lobes
  - Septum pellucidum is absent
  - Anterior horns are fused
  - Occipital horns are separated
  - Third ventricle is present
  - Splenium and body of corpus callosum are present with absence of genu and rostrum
  - Facial anomalies are mild

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Sonographic Evaluation of Neonatal Brain Lesions

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Hydranencephaly

- Ischemic lesion said to result from bilateral occlusion of internal carotid arteries during fetal development
  - Between 3rd and 6th month
- Brain tissue destroyed and cerebellum replaced with CSF
- Sonographic findings:
  - Absence of normal brain tissue replaced by CSF
  - Midline structures (IHF, falx, 3rd vent) preserved
  - No flow in carotid arteries
  - May have macrocephaly

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Porencephaly

- Used to describe:
  - A single cavity
  - Multicystic encephalomalacia for multiple cavities
  - Hydranencephaly for a large single cavity with entire disappearance of cerebral hemispheres
- Sonographic findings:
  - Very echogenic localized lesions within distribution of major vessel
    - Considered to correspond to cerebral infarctions
  - After several days echolucencies appear within echogenic areas

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Cystic Lesions

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Choroid Plexus Cysts

- Common in early development
- Normal if single and under 10mm
  - If over 10 mm and numerous, assoc. with chromosomal abnormalities (Trisomy 18)
- Usually unilateral

*When should they resolve by??

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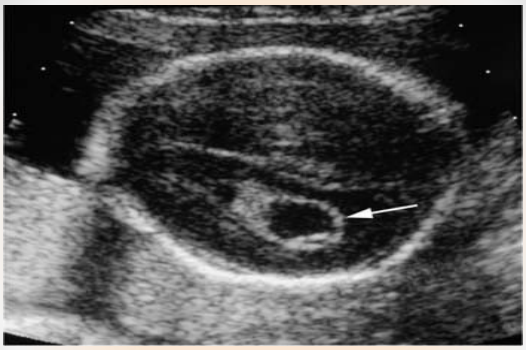

https://radiologykey.com/ruling-out-fetal-anomalies/

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Galenic Venous Malformations

- Aka. Vein of Galen aneurysm, arteriovenous malformation
- Involves arterial communication with the Vein of Galen
- Creates additional flow through right atrium and ventricle, causing CHF
- Sonographic findings:
  - Anechoic mass between lateral ventricles
  - Color flow differentiates it from ither cystic lesions
  - May have hydrocephaly

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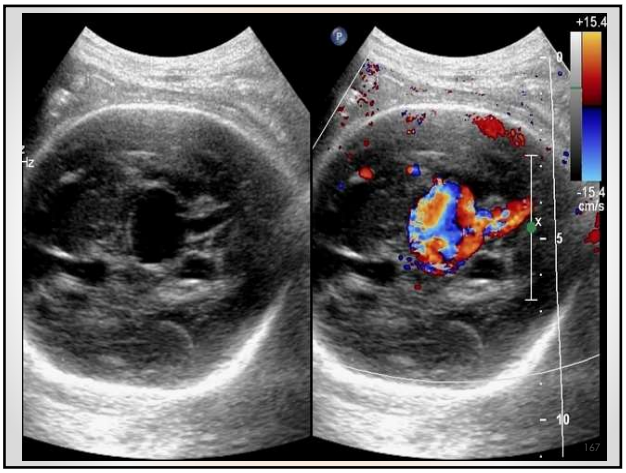

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Subarachnoid Cysts

- Lined by arachnoid tissue and contain CSF
- Most frequent locations:
  - Interhemispheric fissure
  - Suprasellar region
  - cerebral convexities

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Brain Infections

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Ventriculitis

- Common complication of purulent meningitis in newborn infants
- Probably is caused by infection to choroid plexus through blood
- Catheter from a ventriculoperitoneal shunt may provide a route of infection
- First stage
  - Very thin septations extending from walls of lateral ventricles
- Second stage
  - Septa become thicker and lead to multilocular hydrocephalus and extensive disorganization of brain

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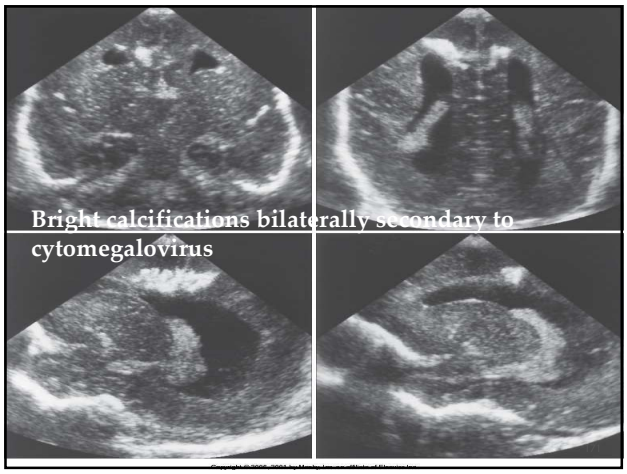

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Ependymitis

- Occurs when the ependymal lining of the ventricles becomes inflamed because of irritation from hemorrhage within the ventricles
- Sonographic findings:
  - Ependymal lining appears thick and hyperechoic

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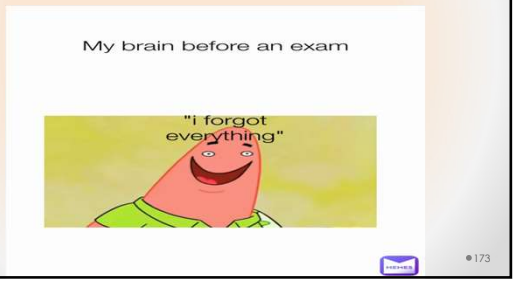
REVIEW!

https://youtu.be/vz7I8nXnfKA



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