Fetal Neural Axis

- Chapter 60

Embryology

- Central nervous system (CNS) arises from the ectodermal neural plate
  - (approximately 18 gestational days)
1. Cephalic neural plate develops into the forebrain
2. Caudal end forms the spinal cord
3. Midbrain and hindbrain then form
   - Neural plate begins to fold

Anencephaly

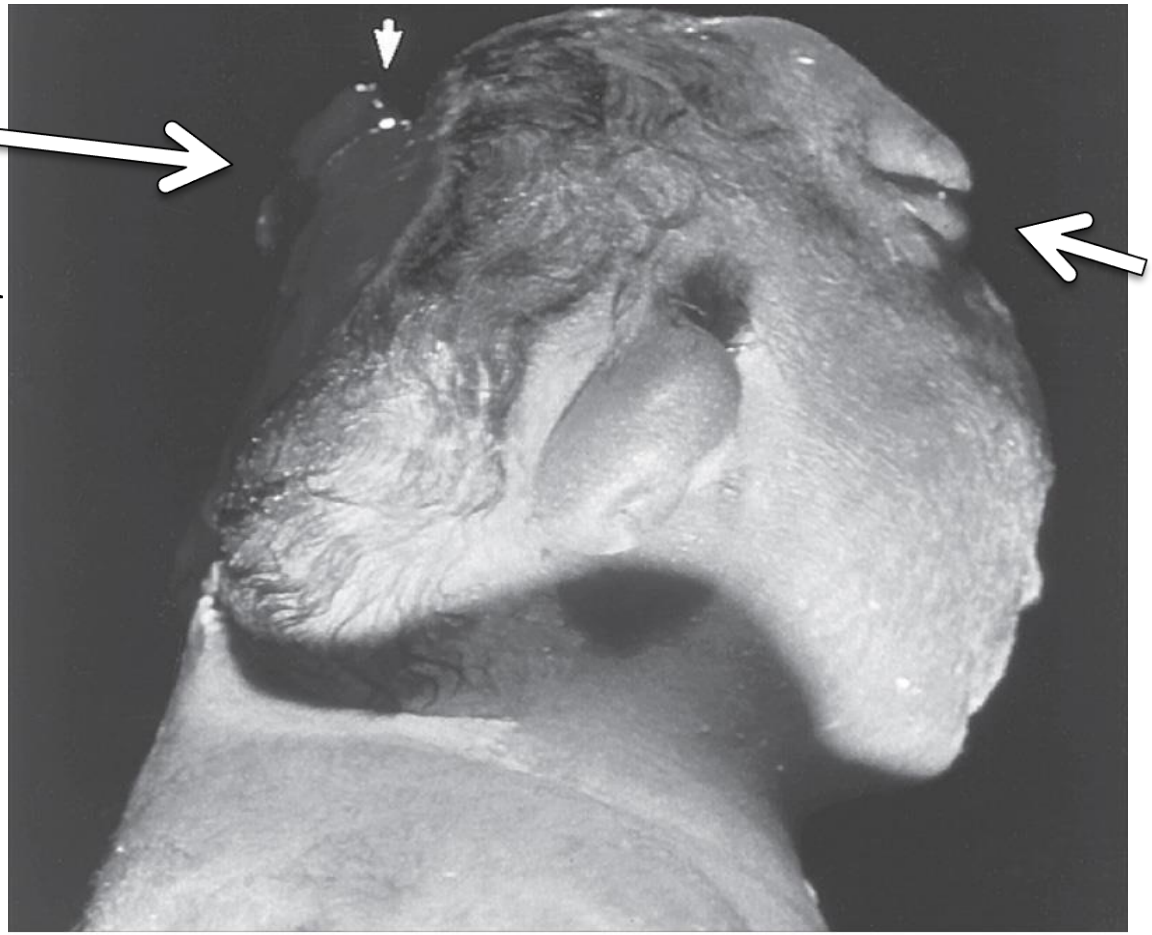
- Most common neural tube defect
  - Approximately 1 in 1000 pregnancies
- Incidence varies with gender
  - Females have a 4 to 1 prevalence over males
- Significant recurrence risk of 2% to 5% for subsequent pregnancies
  - Woman with a history of a prior pregnancy with an open neural tube defect

Anencephaly

- Absence of the brain
  - Caused by failure of the neural tube to close at the cranial end
- Resulting in
  - Absence of the cranial vault
  - Complete or partial absence of the forebrain
    - May partially develop and then degenerate and may have
      - Brainstem
      - Midbrain
      - Skull base
      - Facial structures

Anencephaly

Small Portion of Brain



Froglike

Anencephaly

- Lethal disorder
  - Up to 50% of cases resulting in fetal demise
- Remainder die at birth or shortly after
- Prenatal diagnosis is often made with
  - Ultrasound following referral for increased maternal serum alpha-fetoprotein levels AFP
  - AFP is extremely high with this defect because of the absent skull and exposed tissue

Etiologies of Neural Tube Defects

- Numerous
- Anencephaly may result from
  - Meckel-Gruber syndrome
  - Chromosomal abnormality such as trisomy
- Increased risk in patients with
  - Diabetes mellitus
  - Environmental and dietary factors
    - Folate and vitamin deficiencies
    - High levels of zinc
    - Methotrexate
    - Amniotic band syndrome

Anencephaly

- **May be detected with ultrasound as early as 10 to 14 weeks**
  - **Only sonographic feature may be acrania**
- **CRL may be normal because the degeneration of the fetal brain is progressive**
  - **Leading to a reduction in the crown-rump length with advancing gestation**
- **Second trimester identification of anencephaly is more obvious**
  - **Absent cerebral hemispheres**
  - **Absence of skull**

Anencephaly

- Sonographic findings:
  - Absence of the brain and cranial vault
  - Bulging fetal orbits (froglike appearance)
  - Polyhydramnios
    - 40% to 50% of cases
      - May not be present until after 26 weeks
  - Oligohydramnios occasionally may be identified
  - May see spina bifida

Anencephaly

Anencephaly

(Courtesy Ginny Goreczky, Maternal Fetal Center, Orlando, Fla.)

Anencephaly

- Sonographic findings:
  - Additional anomalies include
    - Cleft lip and palate
    - Hydronephrosis
    - Diaphragmatic hernia
    - Cardiac defects
    - Omphalocele
    - Gastrointestinal defects
    - Talipes

Anencephaly

- Sonographic findings:
  - When severe
    - Microcephaly may be confused with anencephaly
      - Presence of the cranium should aid in a definitive diagnosis
  - Other defects that mimic anencephaly
    - Acrania (brain is abnormal but present)
    - Cephalocele (brain herniation)
    - Amniotic band syndrome (usually asymmetric cranial defects)

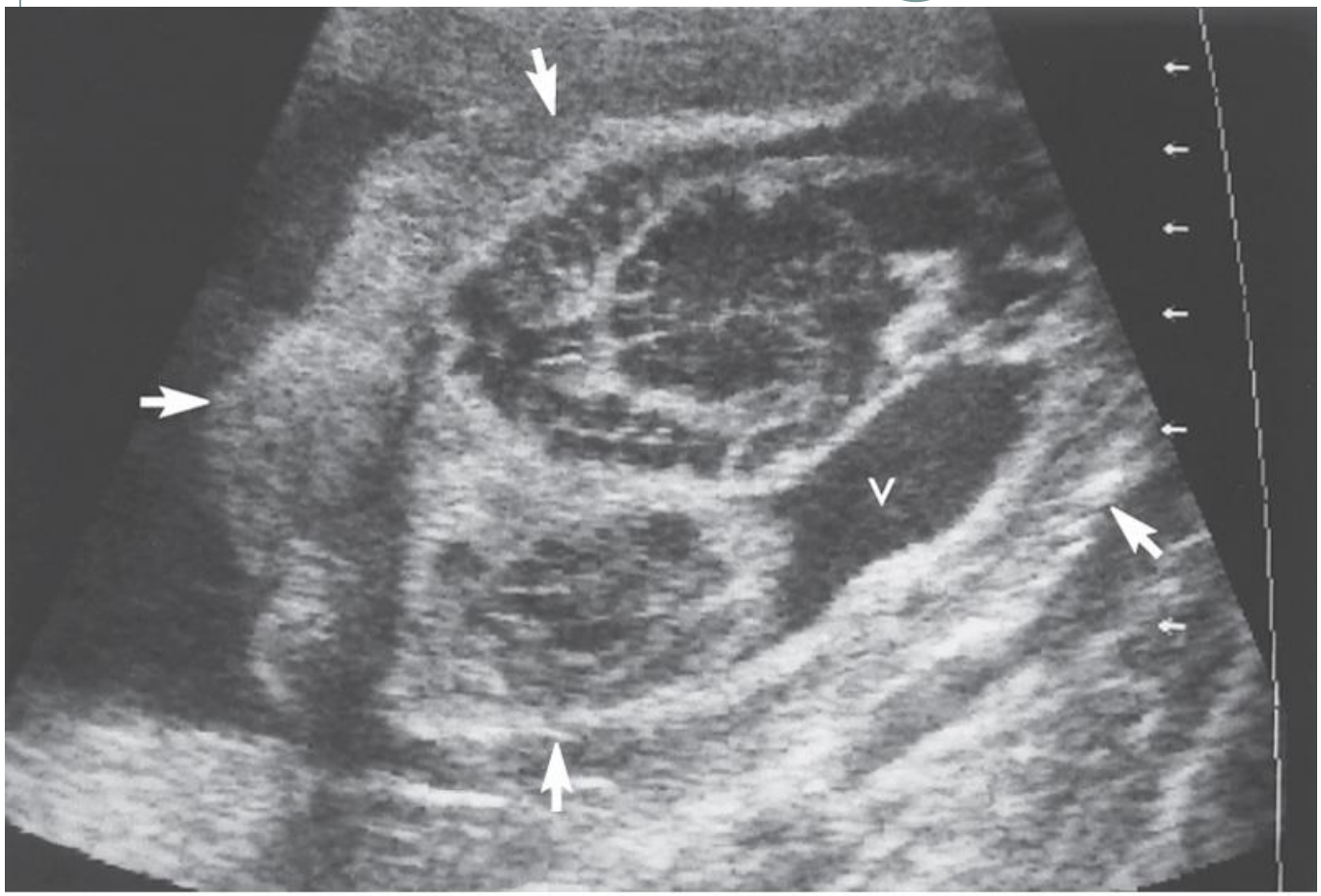
Acrania

- **Absence of the cranial bones**
  - **Presence of complete (abnormal) development of the cerebral hemispheres**
- **Occurs at the beginning of the 4th week**
  - **Mesenchymal tissue fails to migrate**
  - **Does not allow bone formation over the cerebral tissue**
- **Usually progresses to anencephaly as the brain slowly degenerates**
  - **Result of exposure to amniotic fluid**

Acrania

- Sonographic findings:
  - Presence of brain tissue without the calvarium
  - Disorganization of brain tissue
  - Prominent sulcal markings
- May be associated with other anomalies
  - Spinal defects
  - Cleft lip and palate
  - Talipes
  - Cardiac defects
  - Omphalocele
  - Amniotic band syndrome

Acrania



disorganized and freely floating brain tissue *(arrows)*

Acrania

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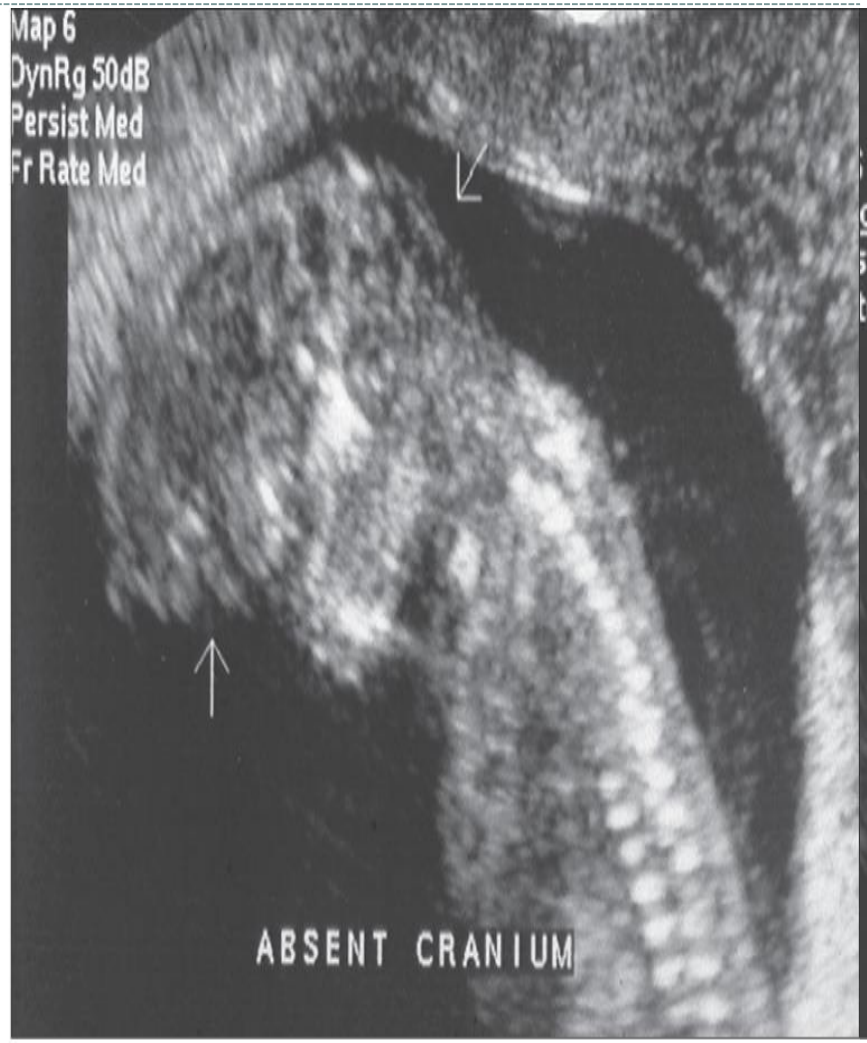
Acrania



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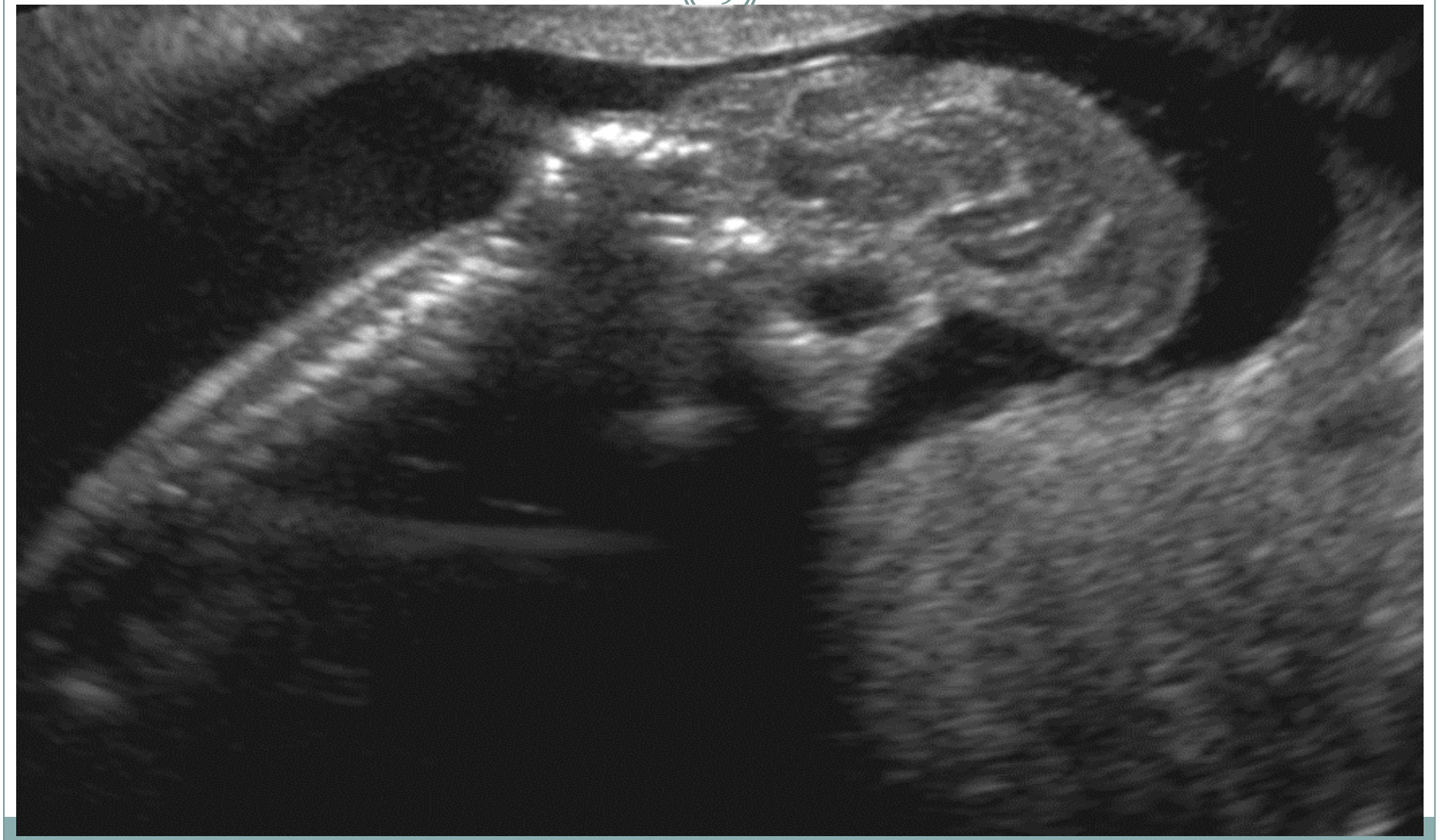
Acrania

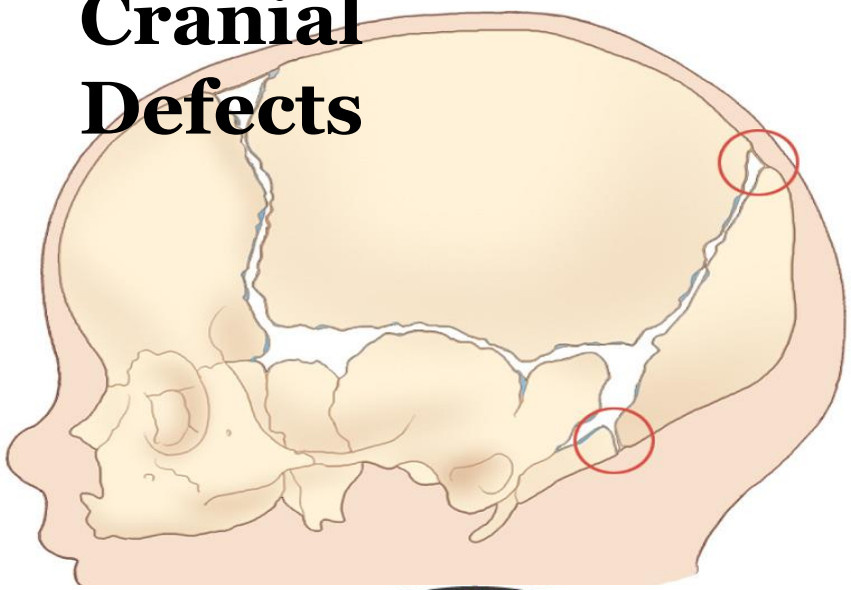


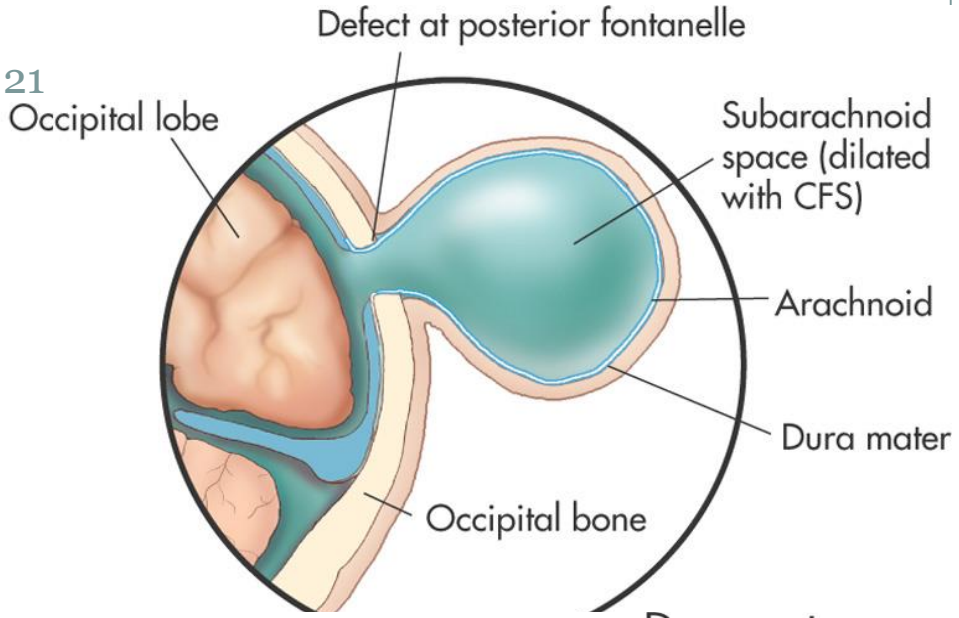
Cephalocele

- Neural tube defect involving herniation through a defect in the calvarium
  - Meninges
  - Meninges and brain
- Encephalocele
  - Hernition of the meninges and brain
- Meningocele
  - Herniation of meninges only

Cephalocele

Cranial Defects





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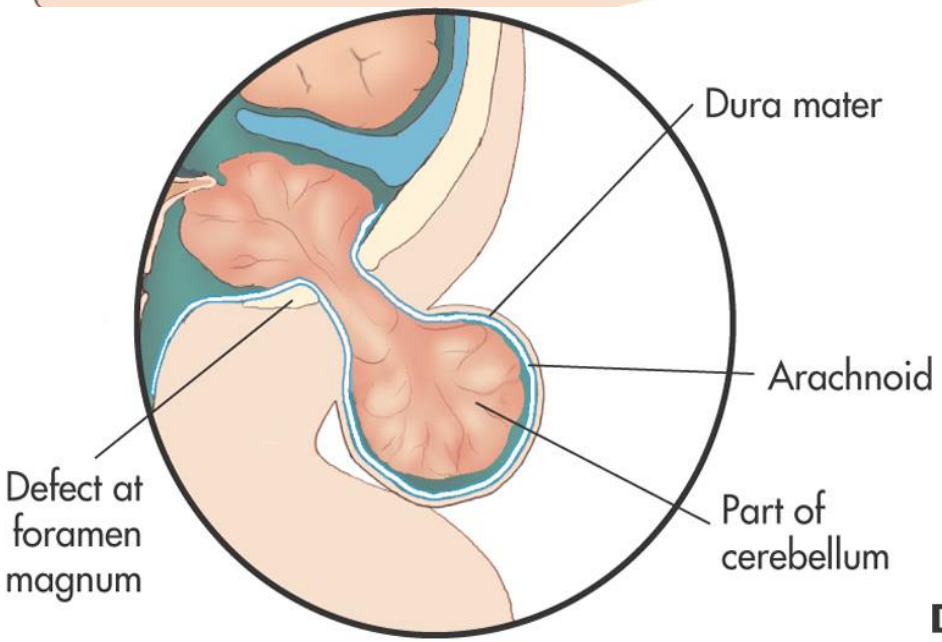

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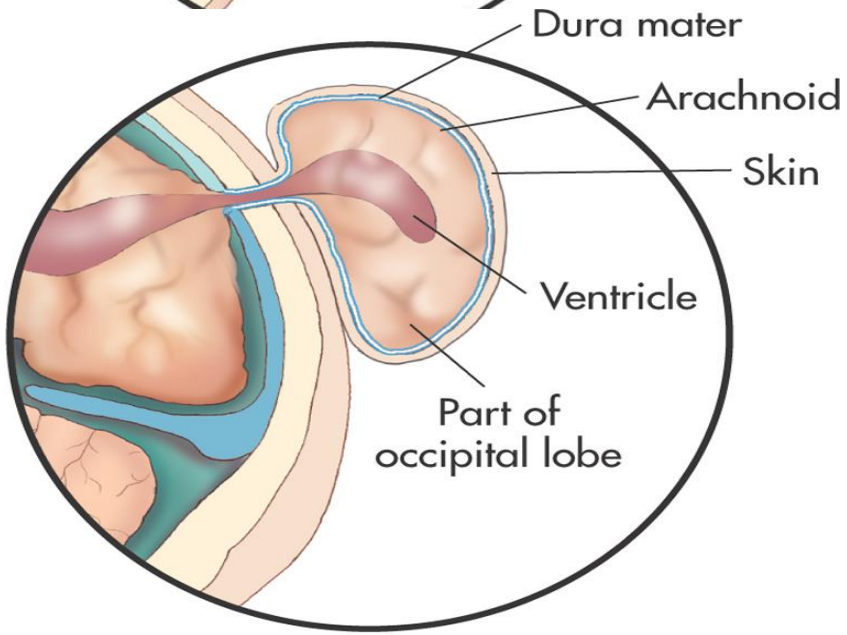

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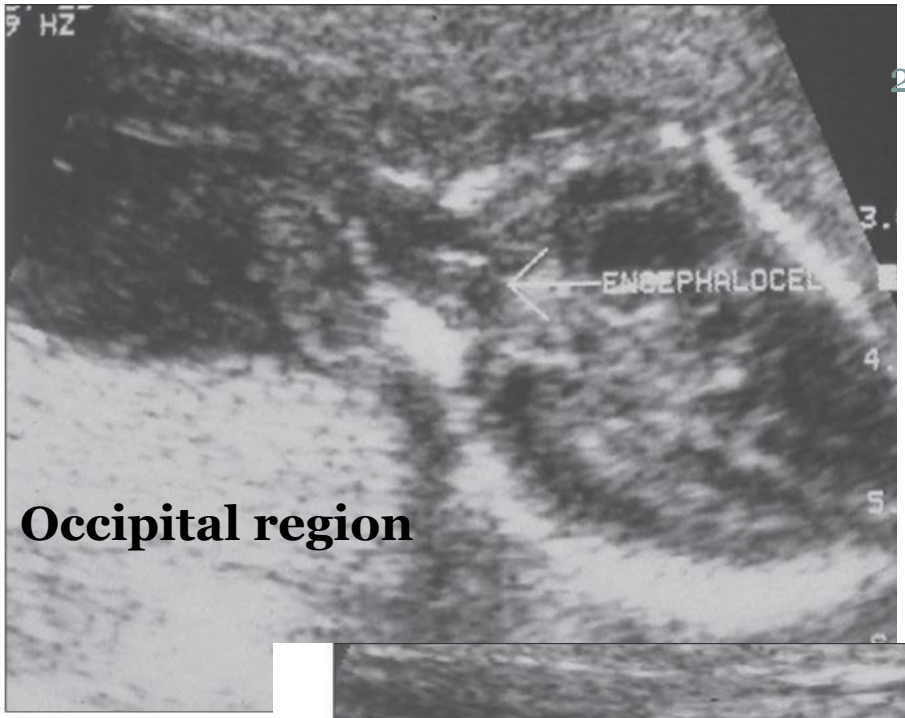
Encephalocele

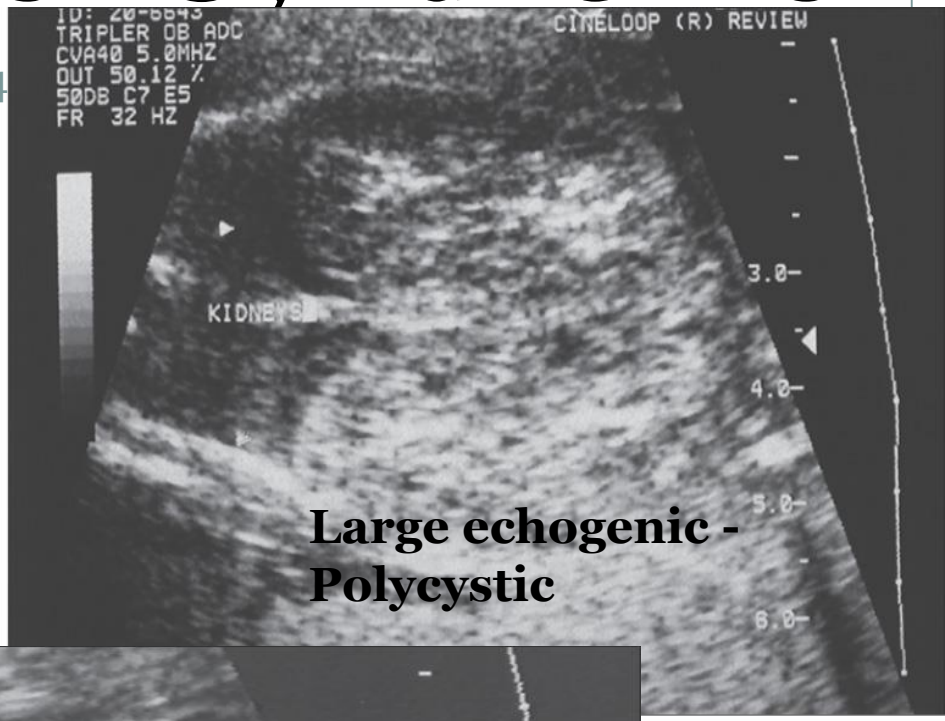
Posterior Occipital

Encephalocele

Meckel-Gruber Syndrome



Occipital region



Large echogenic - Polycystic

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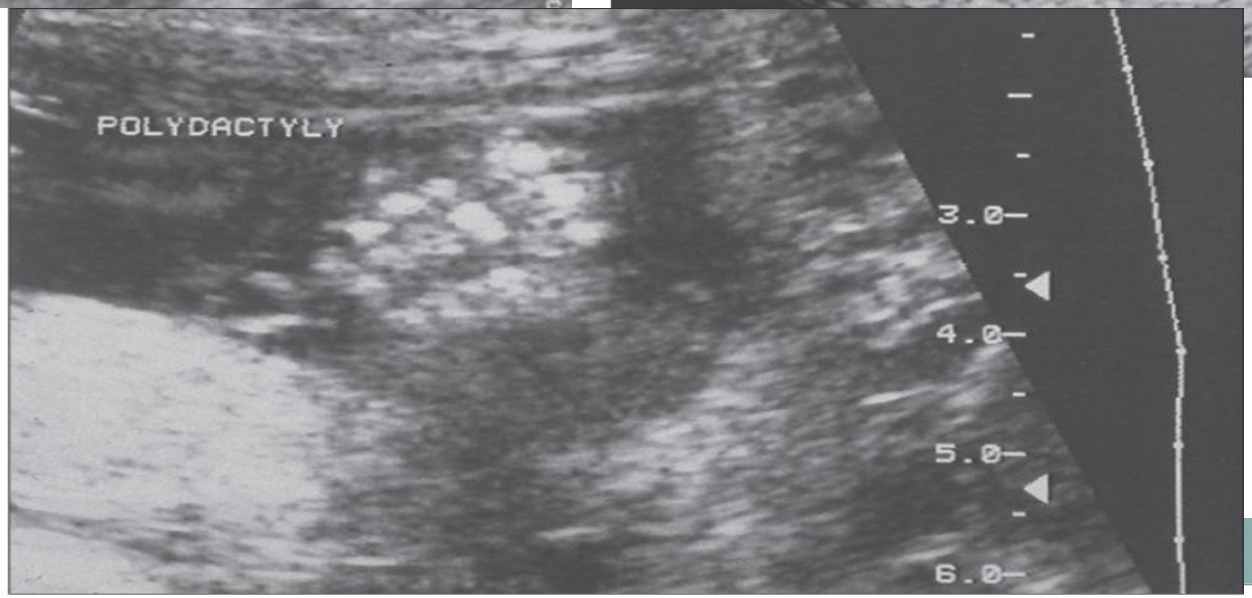

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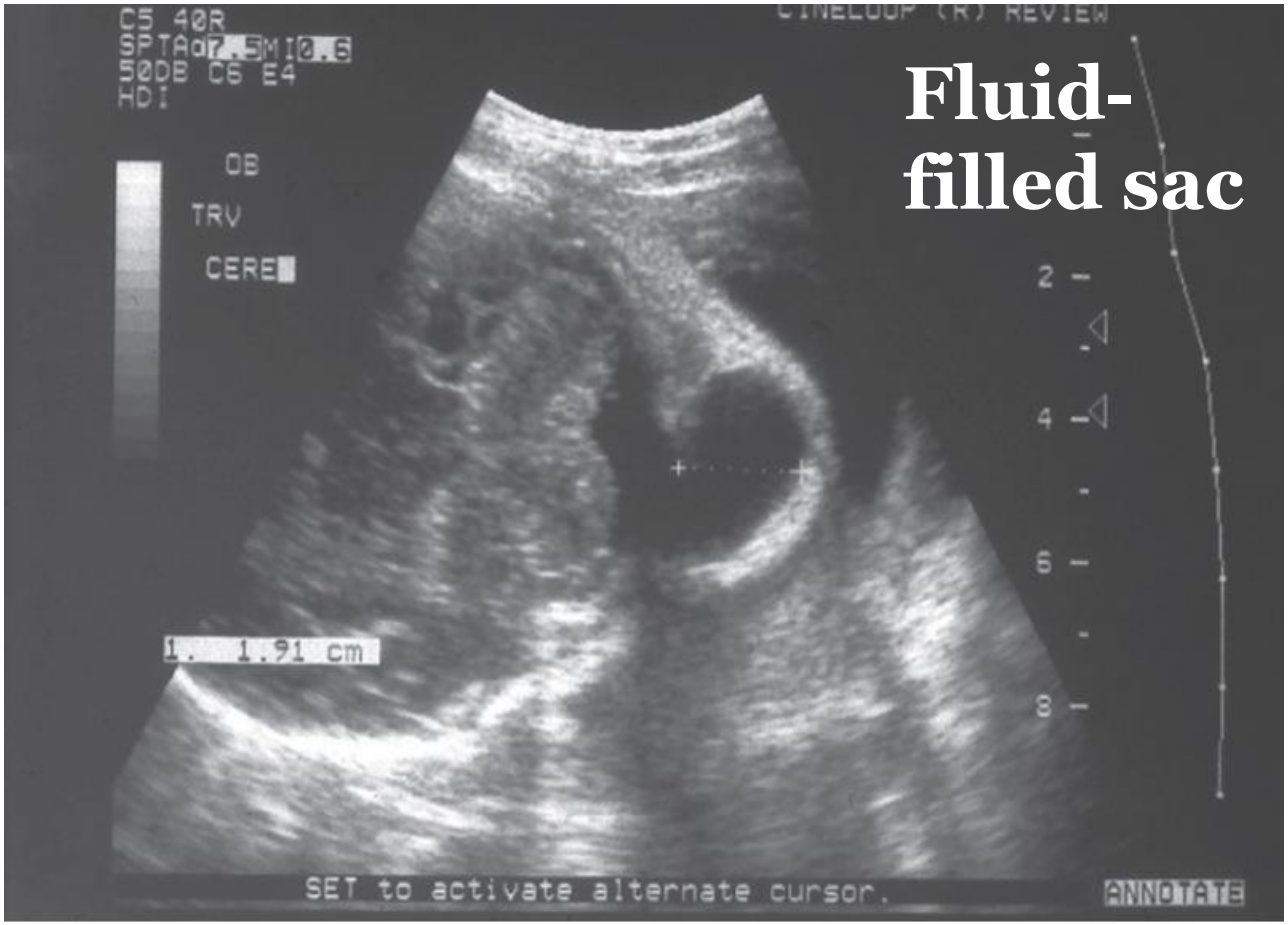
Meningocele



Cephalocele

- Occur 1 to 3 in 10,000 live births
- Involve the occipital bone
  - Located midline in 75% of cases
  - May involve
    - Parietal region
    - Frontal region
    - Temporal region

Cephalocele

- Prognosis based on the size, location, and involvement of other brain structures
  - Worsens prognosis
    - Presence of brain in the defect
    - Microcephaly
    - Other anomalies
- Meningocele may have a normal outcome

Cephalocele

- **Sonographic findings:**
  - **Extracranial mass may**
    - **Fluid (cranial meningocele)**
    - **Solid components (encephalocele)**
  - **Bony defect in the skull**
  - **Ventriculomegaly**
    - **More commonly identified with an encephalocele**
  - **Polyhydramnios**

Spina Bifida

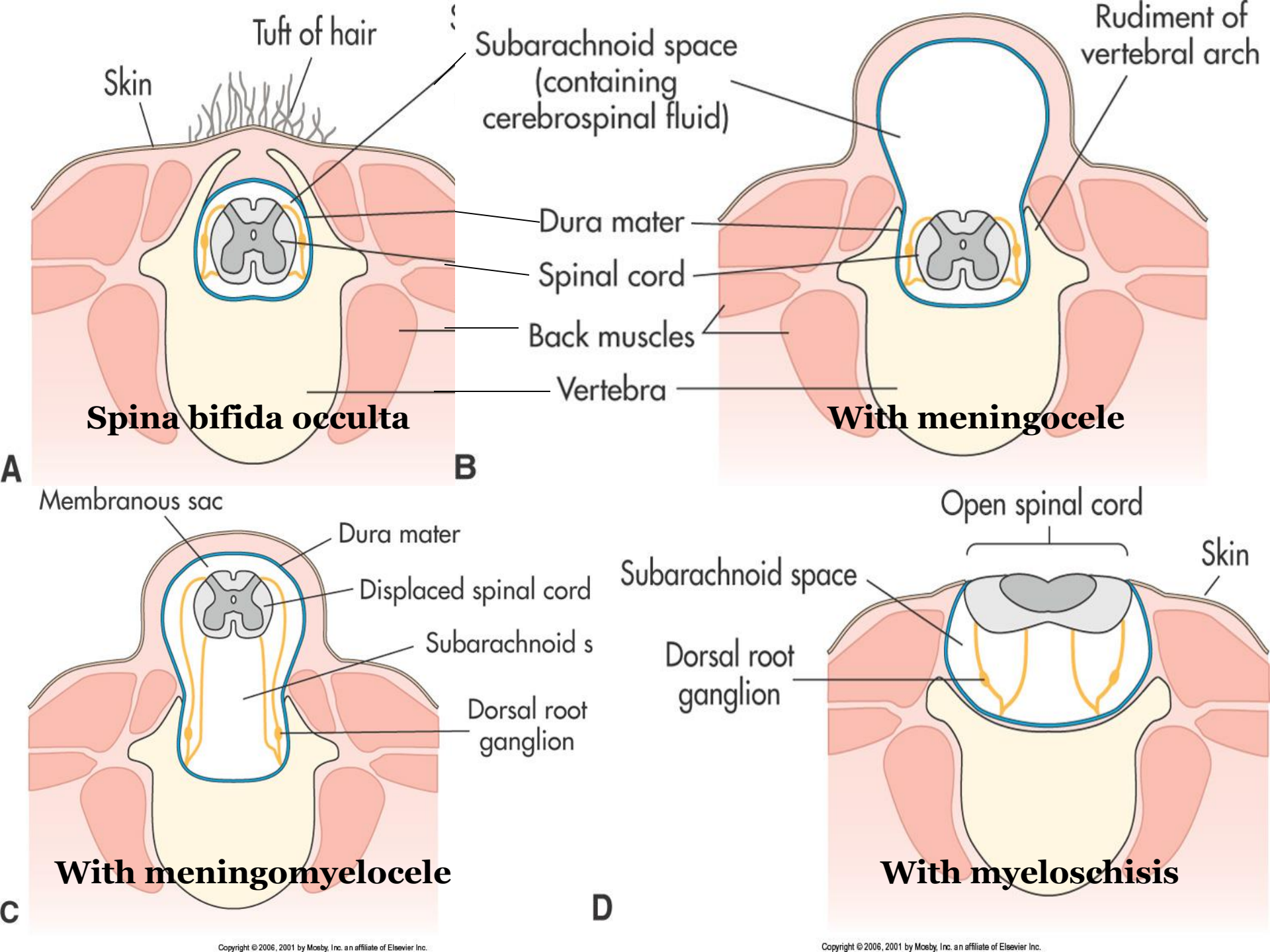
- Second most common open neural tube defect
- Wide range of vertebral defects
  - Results from failure of neural tube closure
  - May occur anywhere along the vertebral column
    - Most common (lumbar/sacral regions)
  - Meninges and neural elements may protrude through this defect

Spina Bifida

- Means that there is a cleft or opening in the spine
- "Spina bifida occulta"
  - Covered with skin or hair
  - Anomaly associated with a normal spinal cord and nerves and normal neurologic development
  - Extremely difficult to detect in the fetus
- Because the defect is covered by skin
  - Maternal serum alpha-fetoprotein level is normal

Spina Bifida

- Meningocele
  - Defect involves protrusion of the meninges only
- Meningomyelocele
  - Meninges and neural elements protrude through the defect
- Rachischisis
  - Defect is very large and severe



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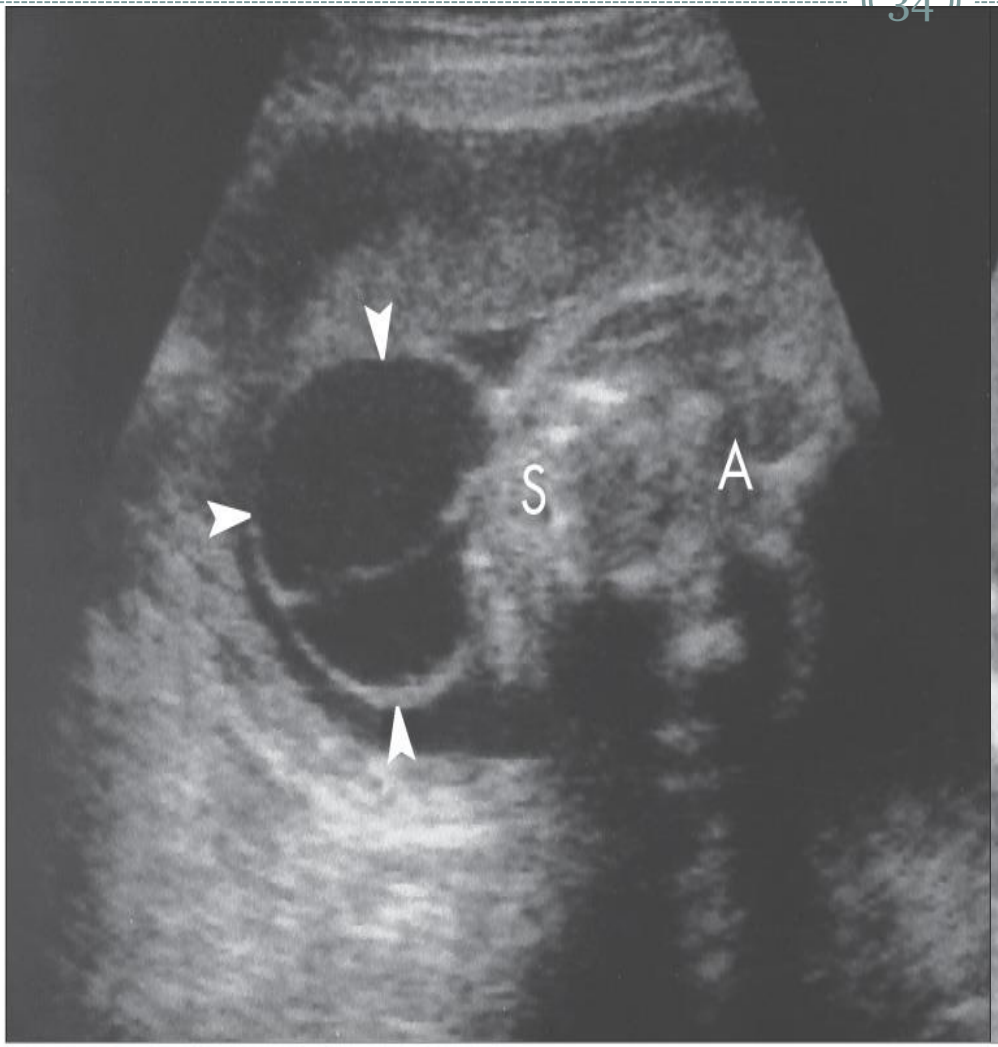
Meningomyelocele

Meningomyelocele



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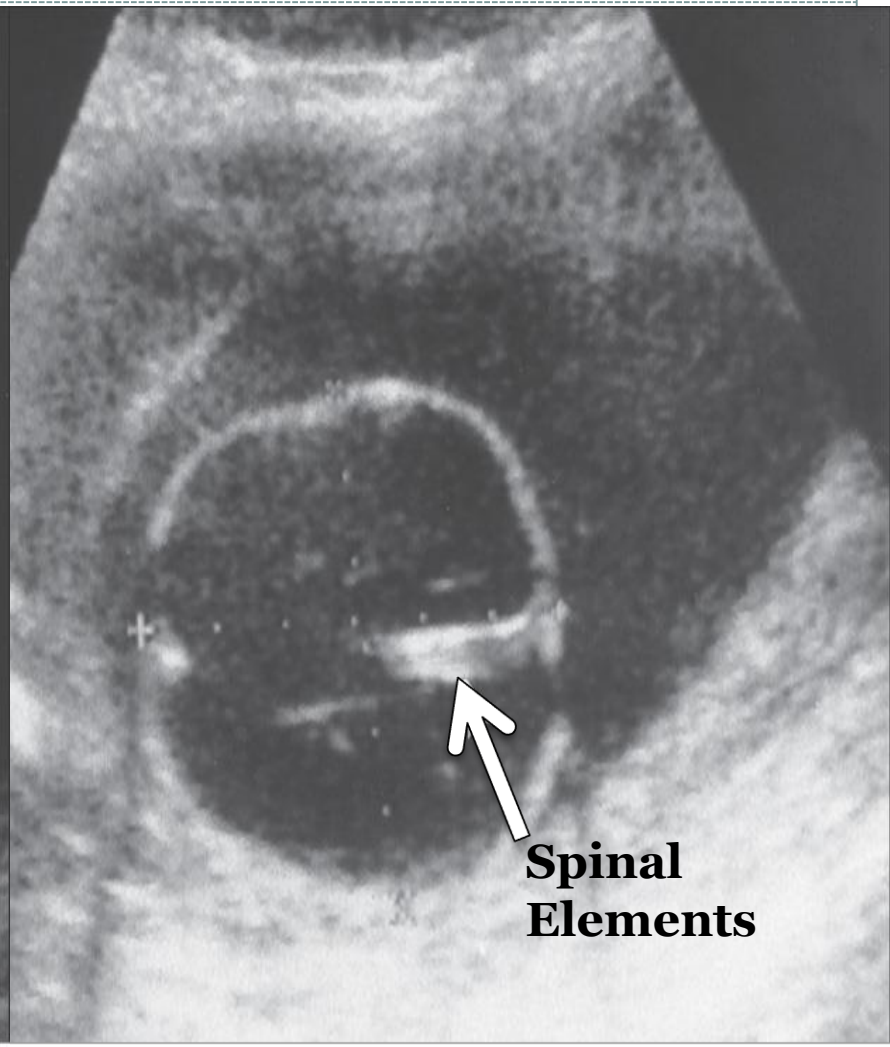
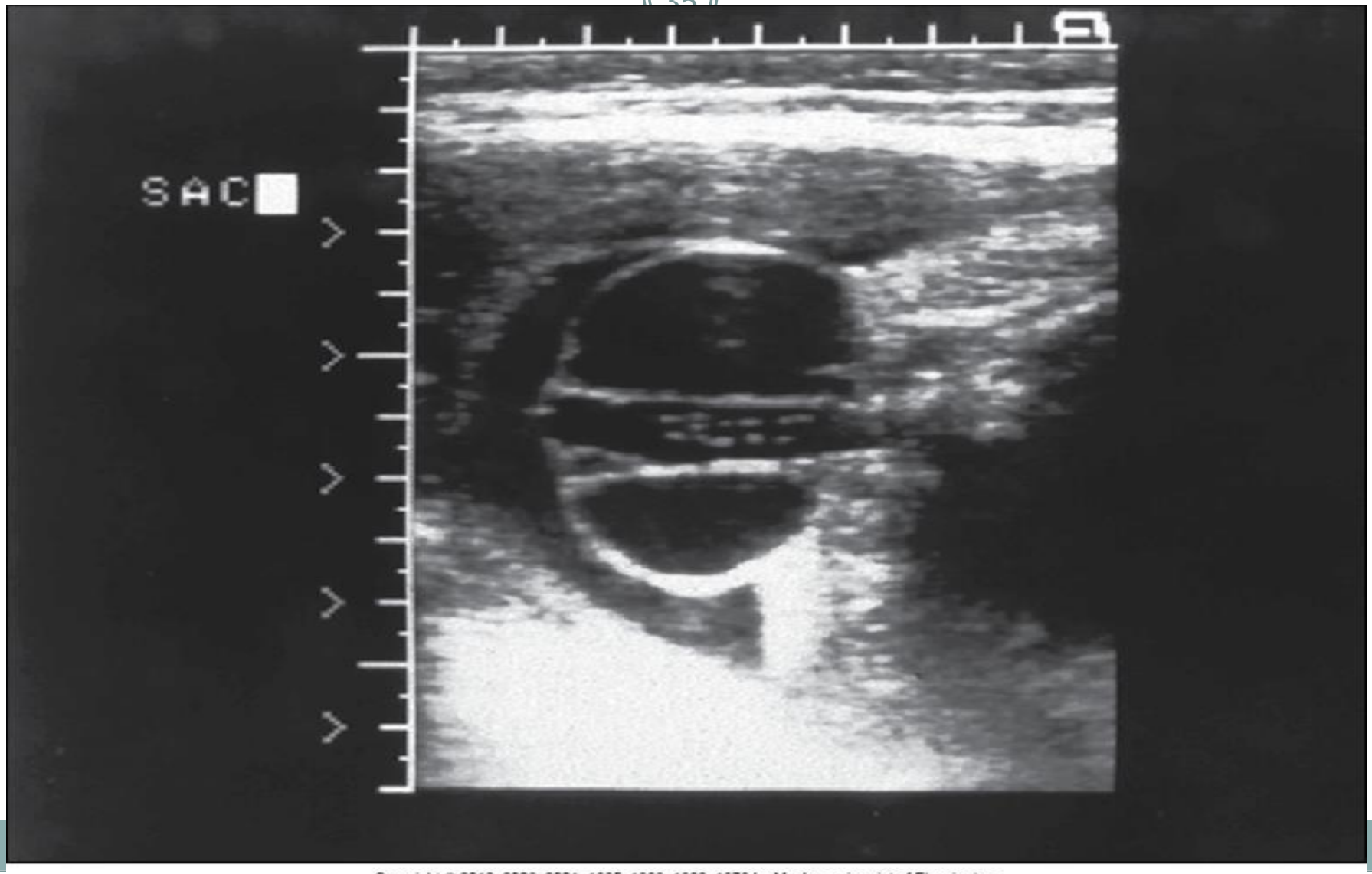
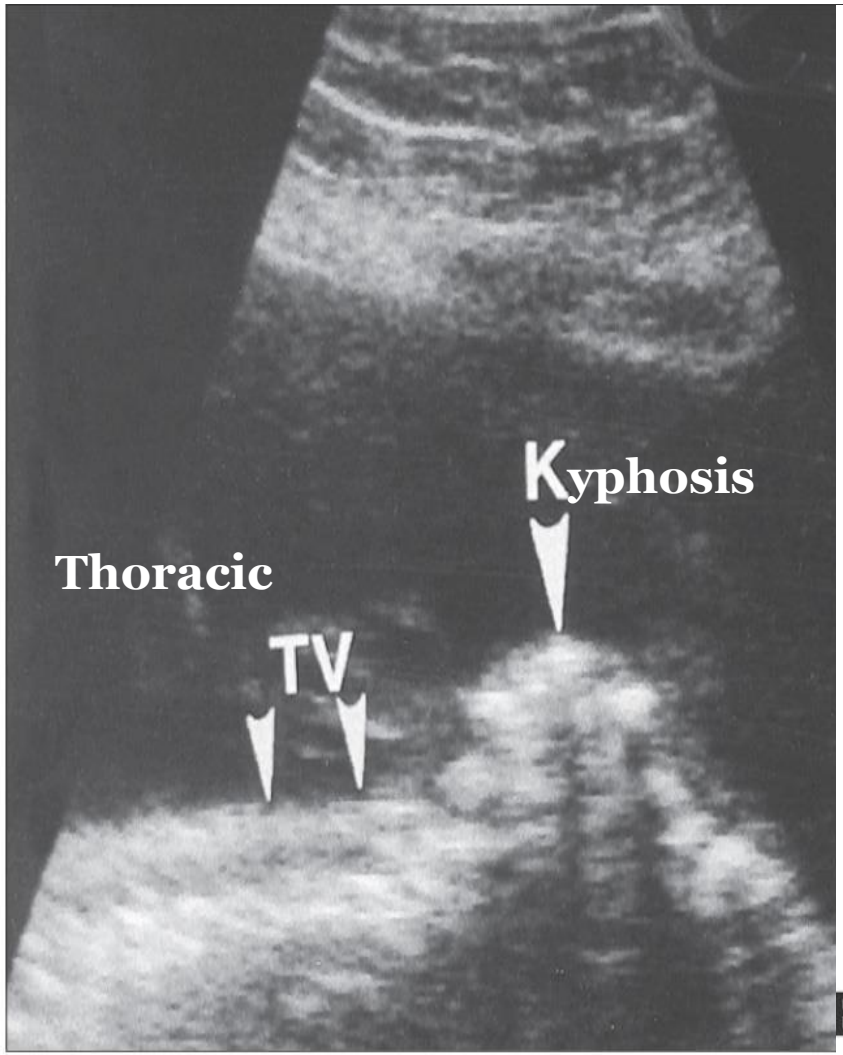


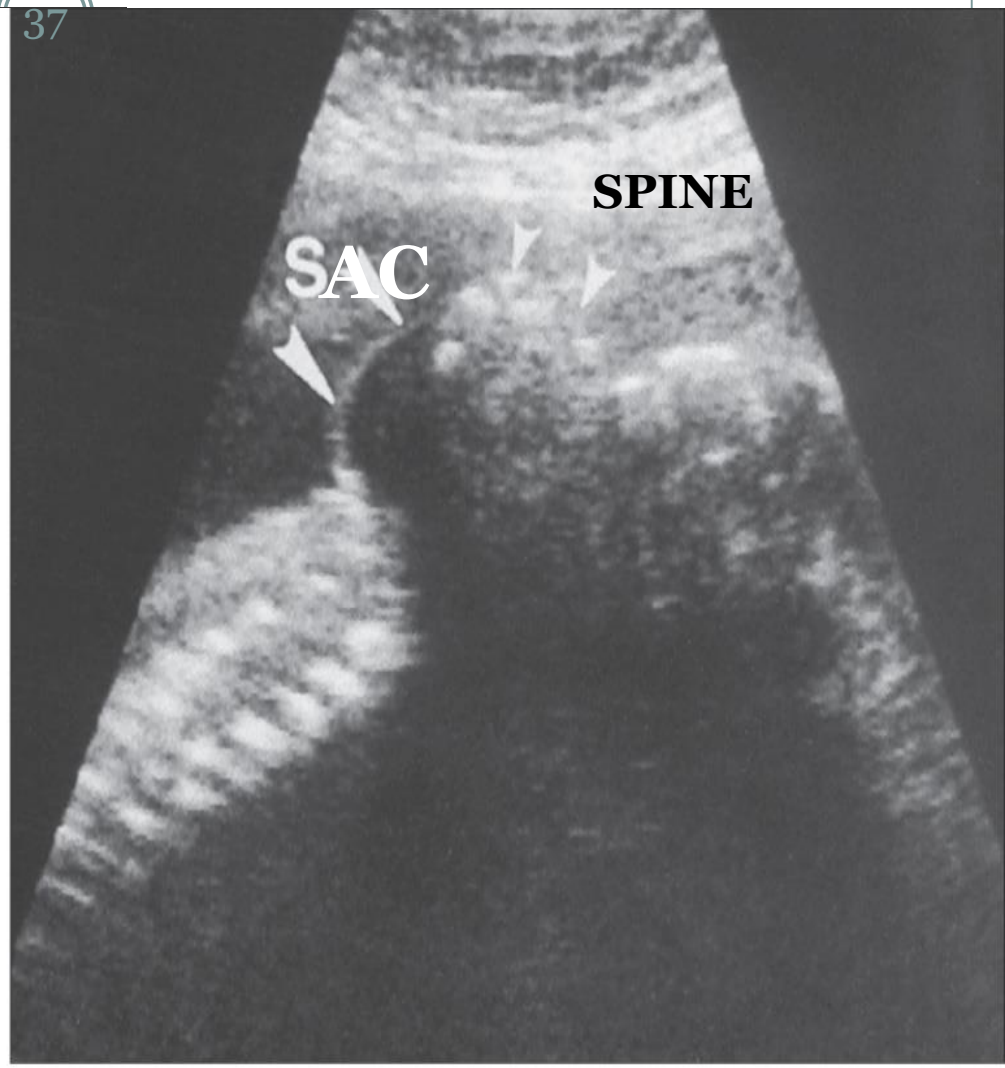
Meningomyelocele



Ventriculomegaly in a fetus with meningomyelocele. Lemon-shaped frontal bones

Meningomyelocele





Spina Bifida

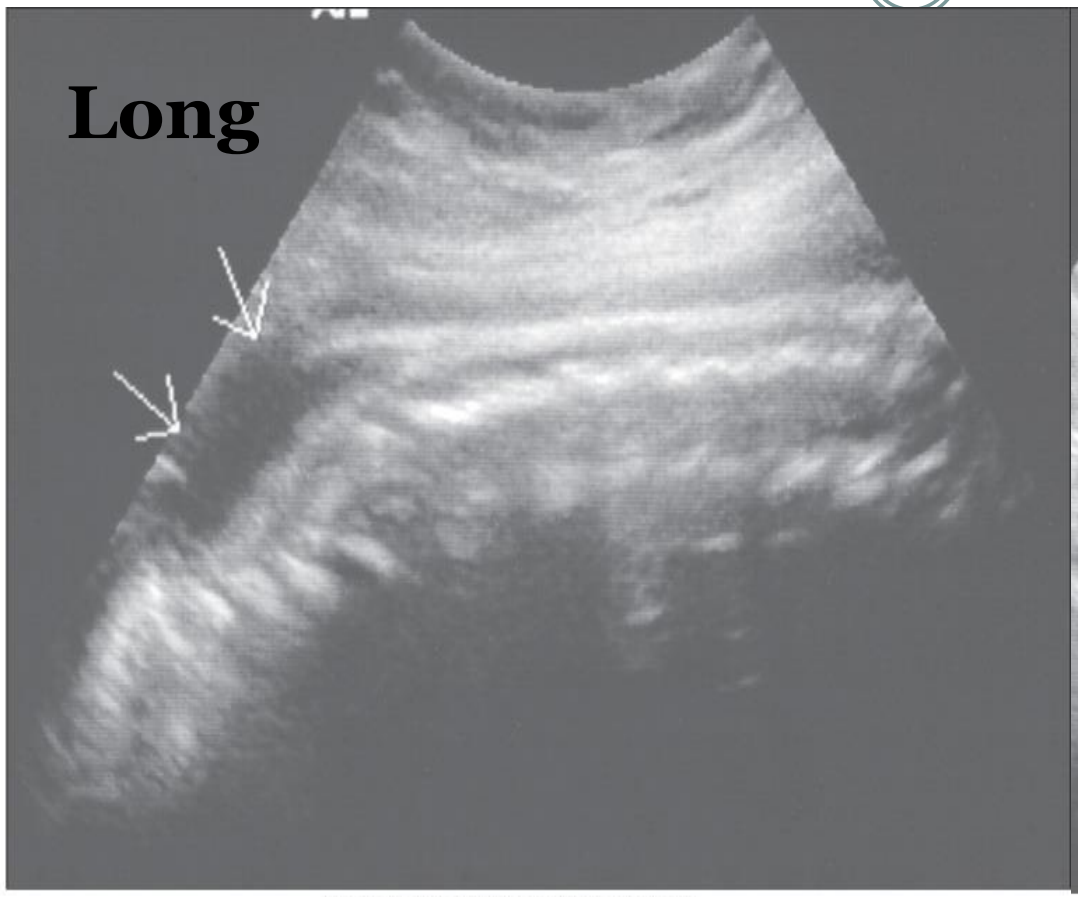
- **Sonographic examination of the fetal spine should include a methodical survey of the spine in the sagittal and transverse planes**
- **Sonographic findings:**
  - **Normal fetal spine should demonstrate the posterior ossification centers completing a spinal circle**

Spina Bifida

Large spinal defect thoracic level

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

Spina Bifida



(Courtesy Ginny Goreczky, Maternal Fetal Center, Orlando, Fla.)

(Courtesy Ginny Goreczky, Maternal Fetal Center, Orlando, Fla.)

Lumbar level

Spina Bifida

- **Survey of the fetal spine may be impeded when**
  - **Spine in down**
  - **Fetus is in the breech position**
  - **Oligohydramnios is present**
  - **Maternal obesity**

Spina Bifida

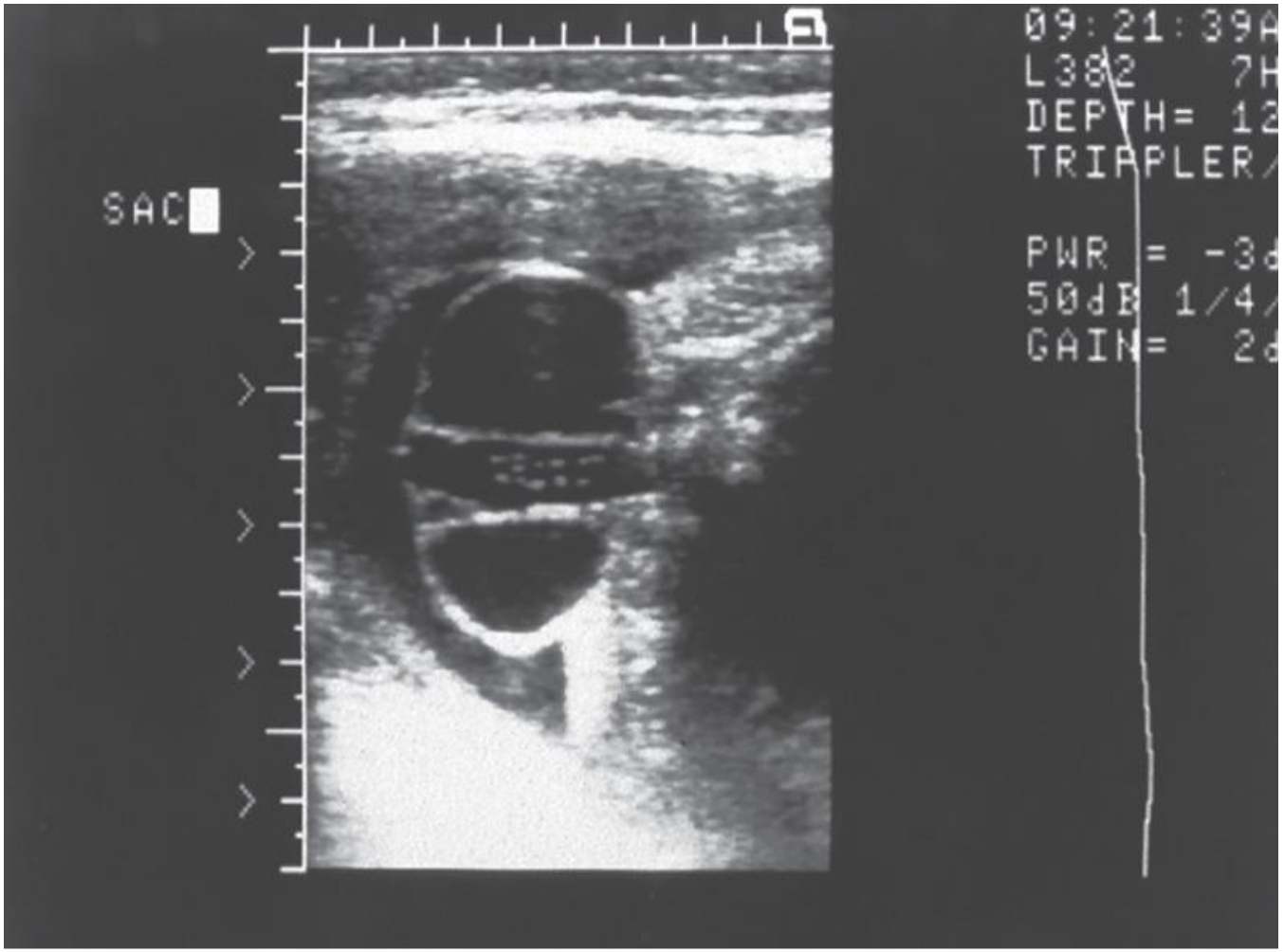
- **Sonographic features of spina bifida include the following:**
  - **Splaying of the posterior ossification centers with a V or U configuration**
  - **Protrusion of a saclike structure that may be**
    - **Anechoic (meningocele)**
    - **Contain neural elements (myelomeningocele)**
  - **Cleft in the skin**

Spina Bifida

Meningomyelocele with the spinal splaying appearing as a "V"

U-shaped and open cleft in the skin

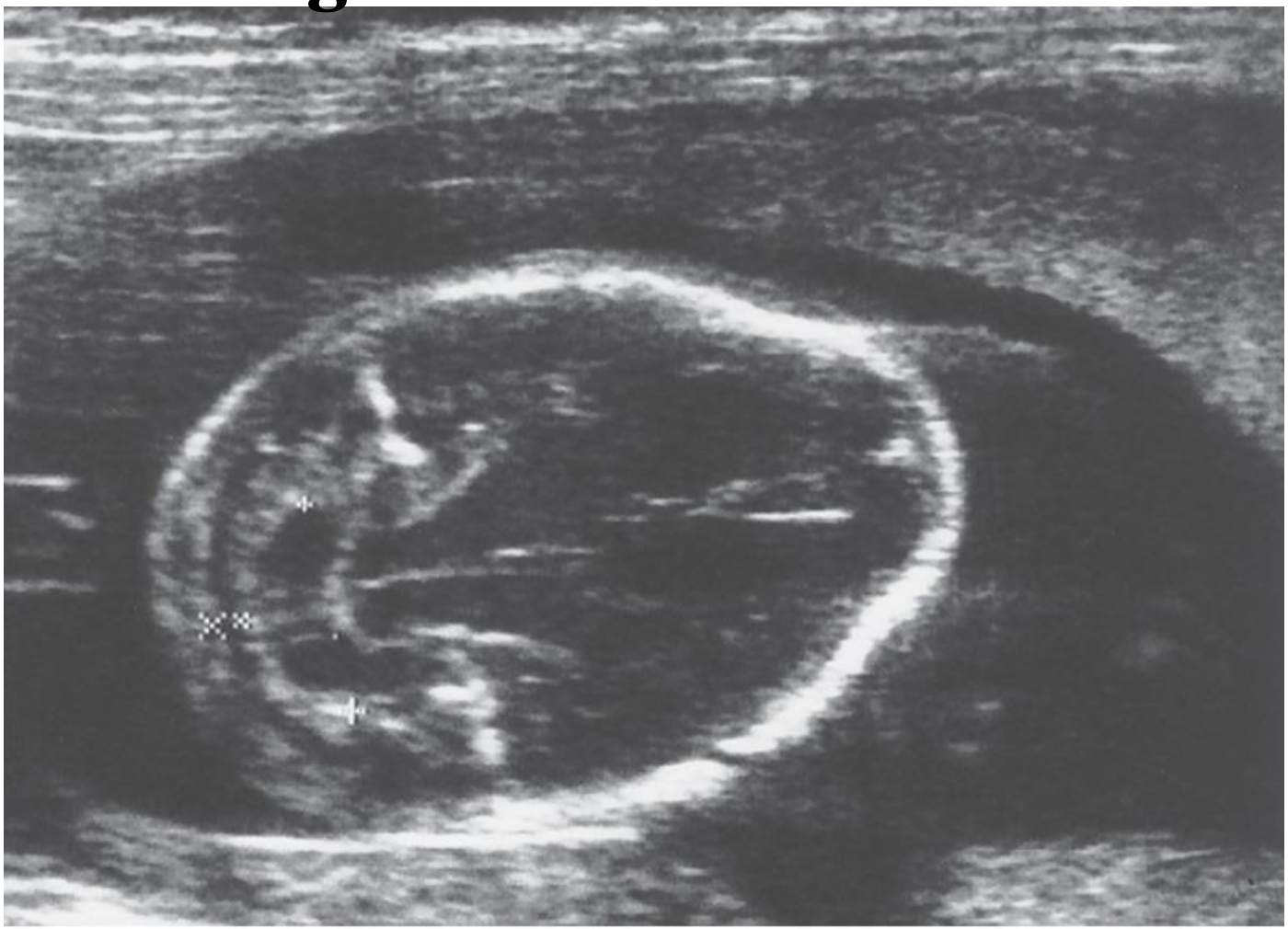
Meningomyelocele
Neural elements protruding into the sac



Spina Bifida

- After a spinal defect has been identified, the following should be documented
  - Level and extent of the defect
  - Presence or absence of neural elements contained in the protruding sac
  - Associated intracranial findings
    - Flattening of the frontal bones
      - Giving the head a “lemon” shape
    - Obliteration of the cisterna magna
    - Inferior displacement of the cerebellar vermis
      - Giving cerebellum rounded, “banana” shape
    - Ventriculomegaly

Abnormally shaped cerebellum “banana sign” Lemon-shaped frontal bones consistent with frontal bossing



Spina Bifida

- Associated with multiple syndromes and chromosomal anomalies, including trisomy
- Increased risk in patients with
  - Diabetes mellitus
  - Environmental and dietary factors
    - Folic acid deficiency
    - Hyperthermia
    - Methotrexate

Dandy-Walker Malformation

- Defect that may have varying degrees of severity
- Manifests with
  - Agenesis of the cerebellar vermis
  - Hypoplasia of the cerebellar vermis
    - Resulting dilation on the fourth ventricle
- Occurrence rate is 1 in 25,000 to 35,000
- Thought to occur before the 6^{th} or 7^{th} week
  - Result of abnormal embryogenesis of the roof of the fourth ventricle

Dandy-Walker Malformation

- Dandy-Walker variant
  - Milder form
- Dandy-Walker malformation causes 4% of cases of hydrocephalus
  - Hydrocephalus commonly identified
  - Associated with other intracranial anomalies about 50% of the time
    - Agenesis of the corpus callosum
    - Aqueductal stenosis
    - Microcephaly
    - Macrocephaly
    - Encephalocele
    - Lipomas

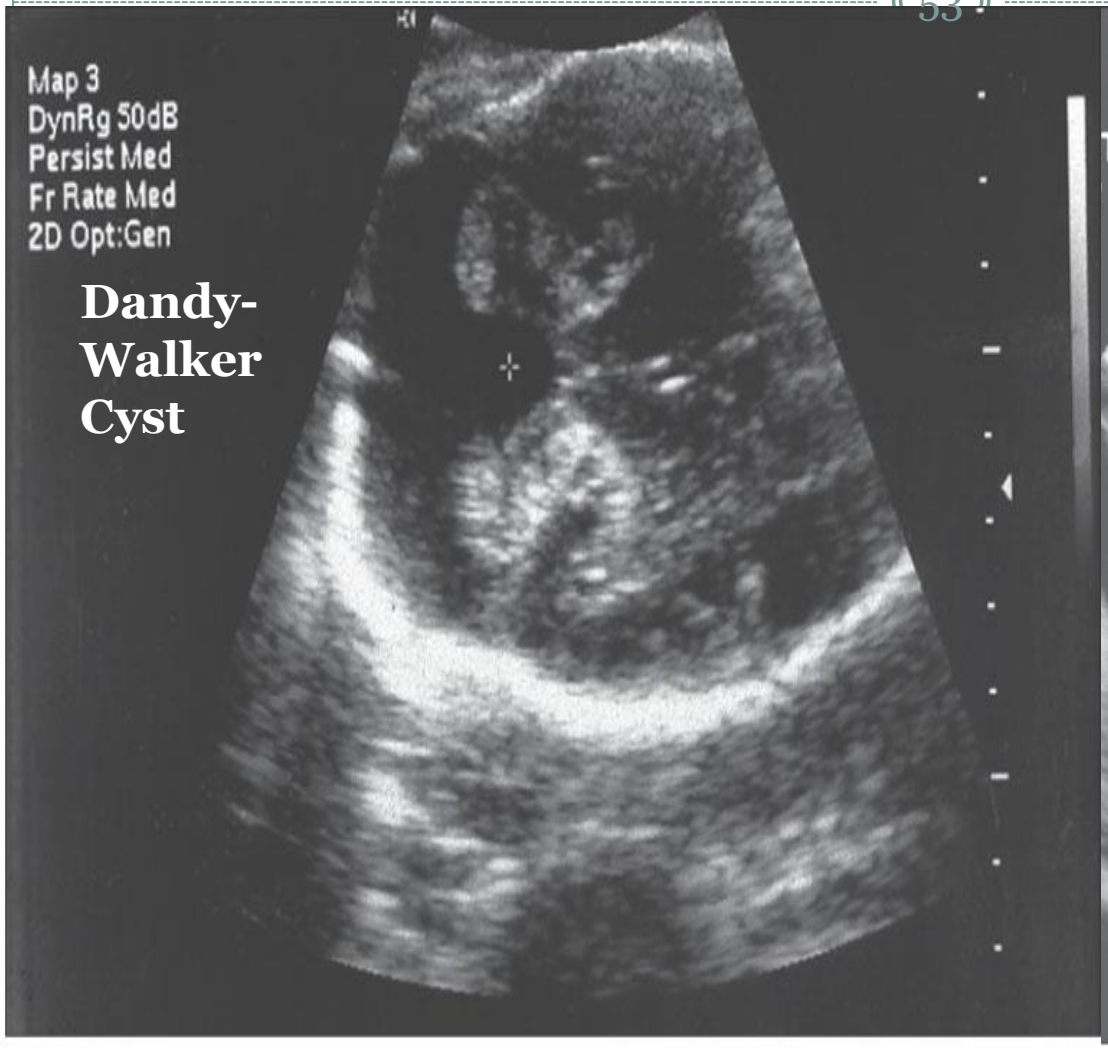
Dandy-Walker Malformation

- Chromosomal anomalies that may be associated with DWM include
  - Trisomies 13
  - Trisomies 18
  - Trisomies 21
- Associated with several syndromes including
- Meckel-Gruber syndrome
- Walker-Warburg syndrome
- Aicardi syndrome
- Linked with congenital infections

Dandy-Walker Malformation

- Sonographic findings:
  - Posterior fossa cyst that can vary considerably in size
  - Splaying of the cerebellar hemispheres as a result of the complete or partial agenesis of the cerebellar vermis
  - Enlarged cisterna magna caused by
    - Cerebellar vermis anomaly
    - Posterior fossa cyst
  - Ventriculomegaly

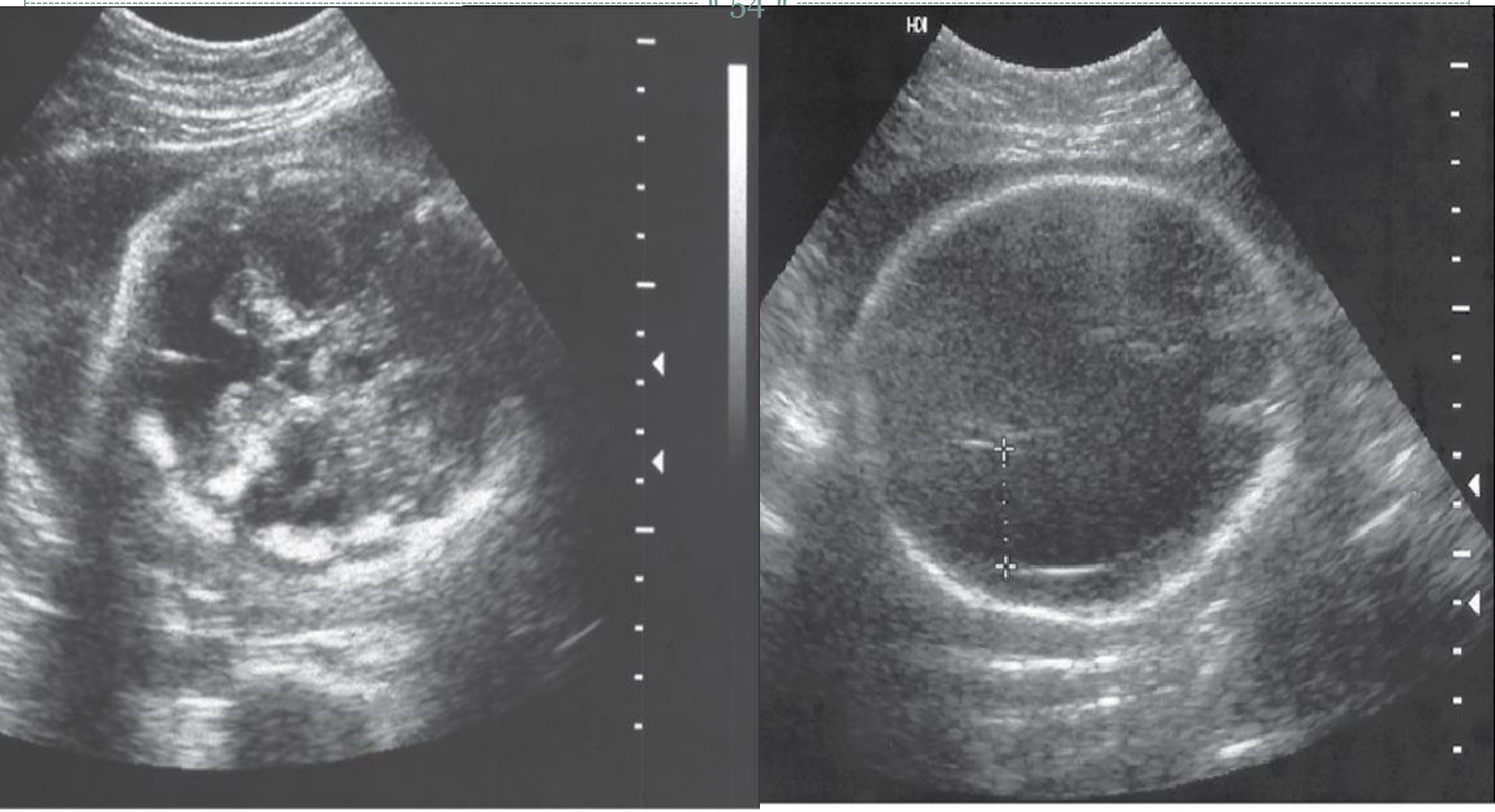
Dandy-Walker Malformation



(Courtesy Ginny Goreczky, Maternal Fetal Center, Florida Hospital, Orlando, Fla.)

(Courtesy Maria Roman, Maternal Fetal Center, Florida Hospital, Orlando, Fla.)

Dandy-Walker Malformation



Holoprosencephaly

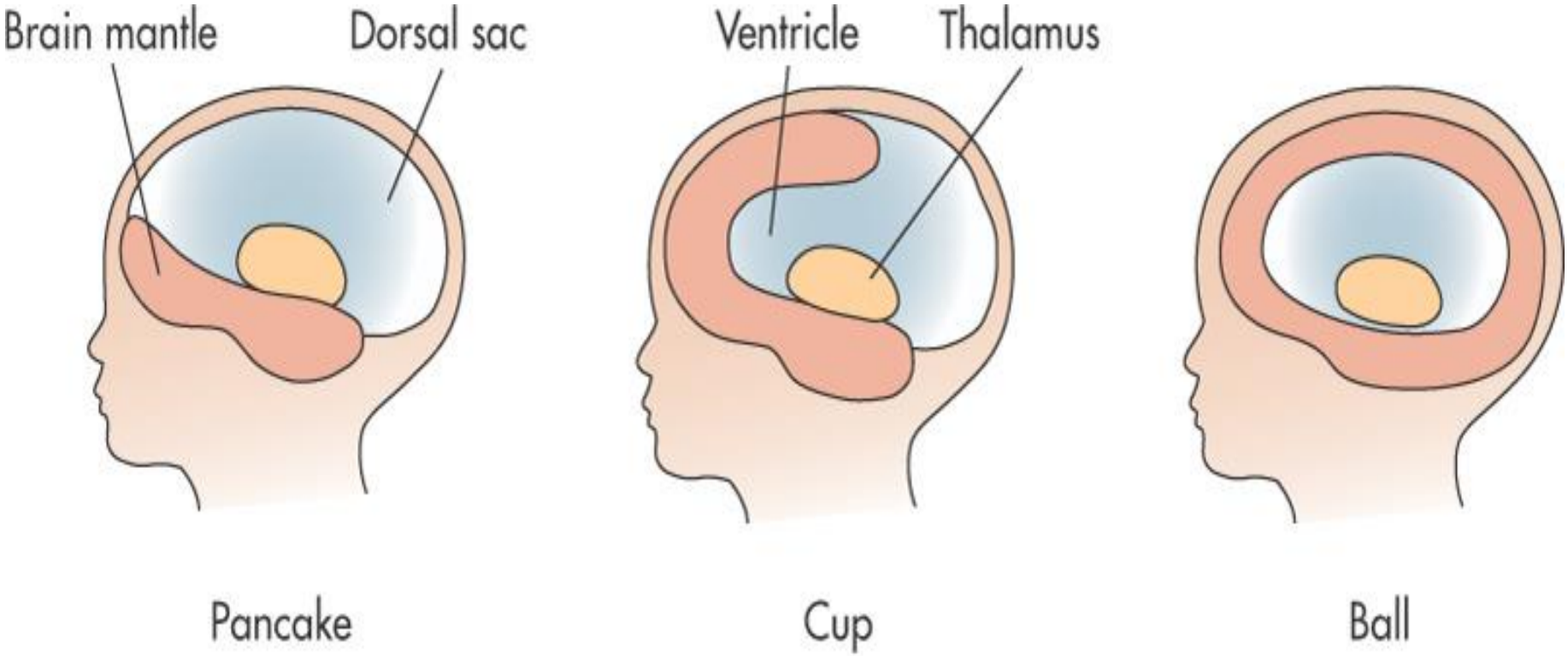
- Encompasses a range of abnormalities resulting from abnormal cleavage of the prosencephalon (forebrain)
- Incidence is 1 in 10,000 to 20,000 live births
- Cases are sporadic or associated with syndromes, genetic factors, or teratogens

Holoprosencephaly

- Three forms
  - Alobar - most severe
  - Semilobar – intermediate
  - Lobar – mildest
- Identification of the specific form depends on the degree of failed hemispheric division

Alobar Holoprosencephaly

- Characterized by
  - Monoventricle
  - Brain tissue that is small and may have a cup, ball, or pancake configuration
  - Fusion of the thalamus
  - Absence of the
    - Interhemispheric fissure
    - Cavum septum pellucidum
    - Corpus callosum
    - Optic tracts
    - Olfactory bulbs



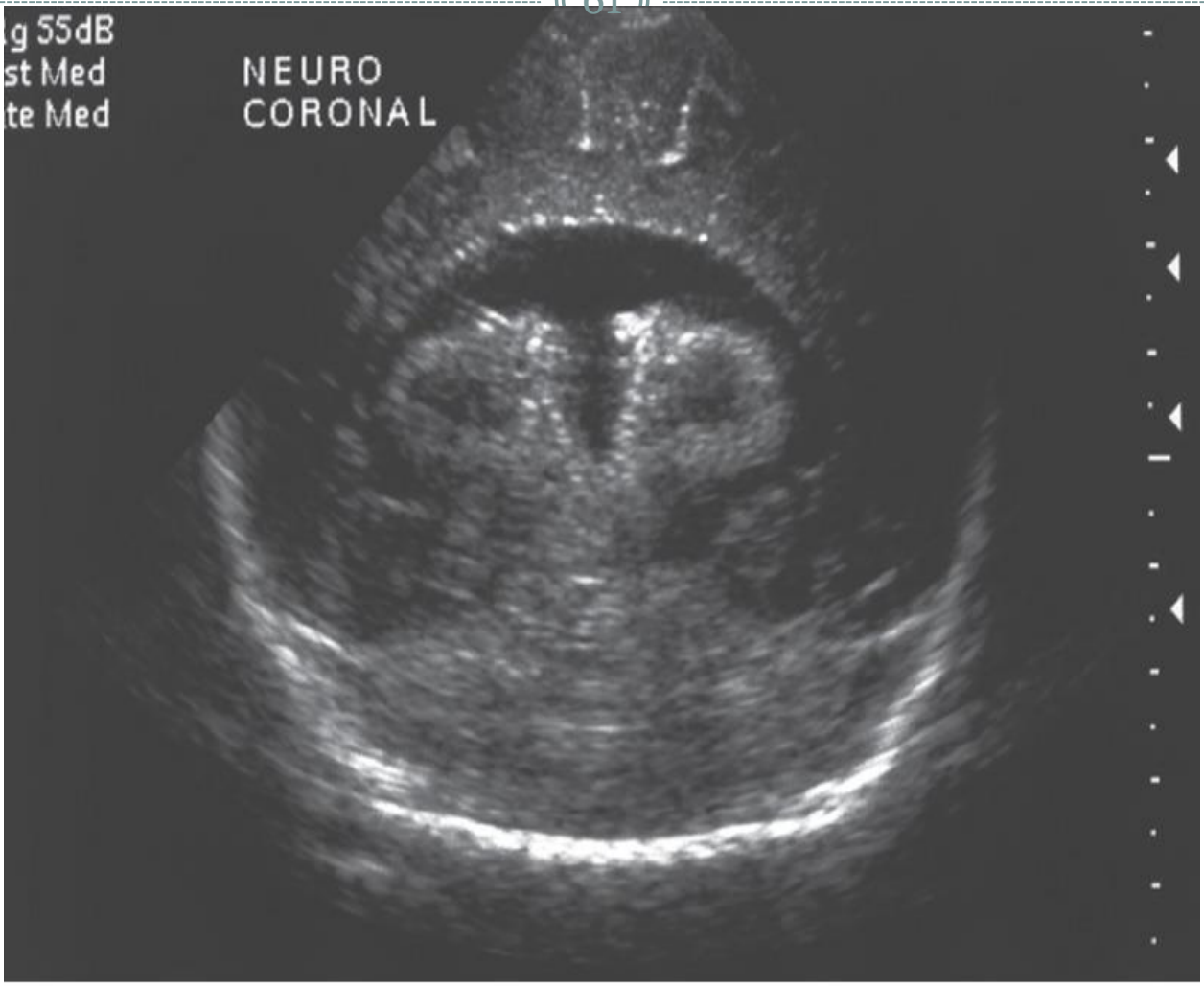
Alobar Holoprosencephaly

Semilobar Holoprosencephaly

- **Presents with a singular ventricular cavity with**
  - **Partial formation of the occipital horns**
  - **Partial or complete fusion of the thalamus**
  - **Rudimentary falx and interhemispheric fissure,**
  - **Absent**
    - **Corpus callosum**
    - **Cavum septum pellucidum**

Olfactory bulbs

Semilobar Holoprosencephaly

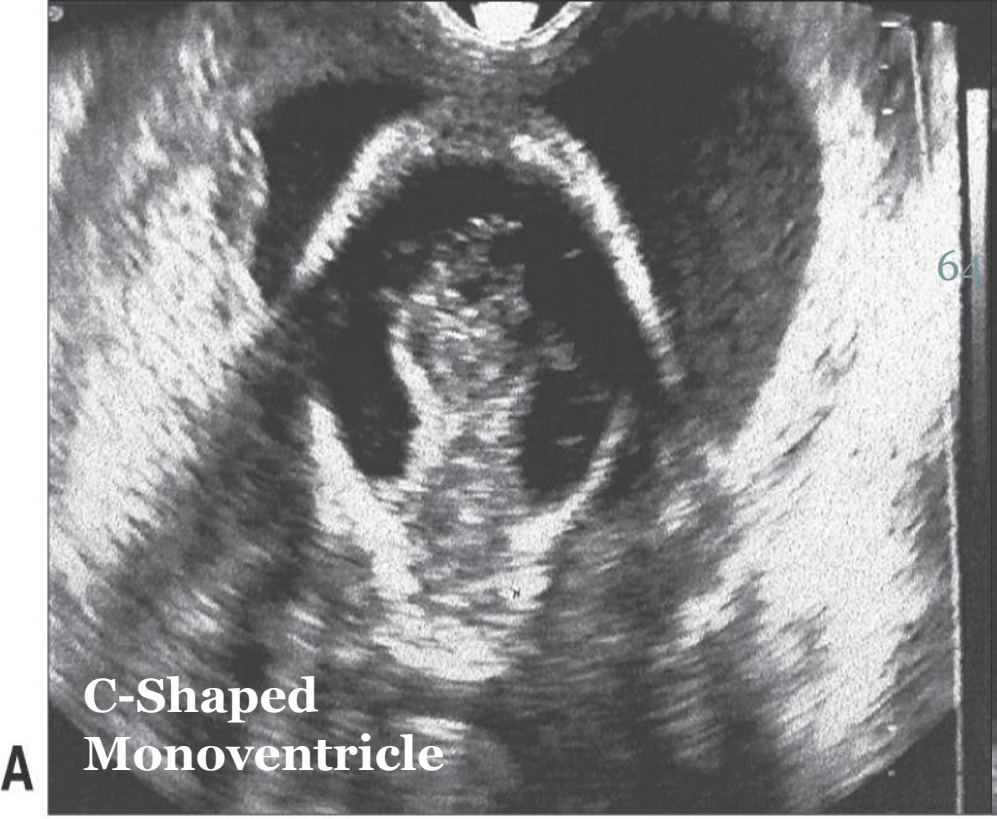


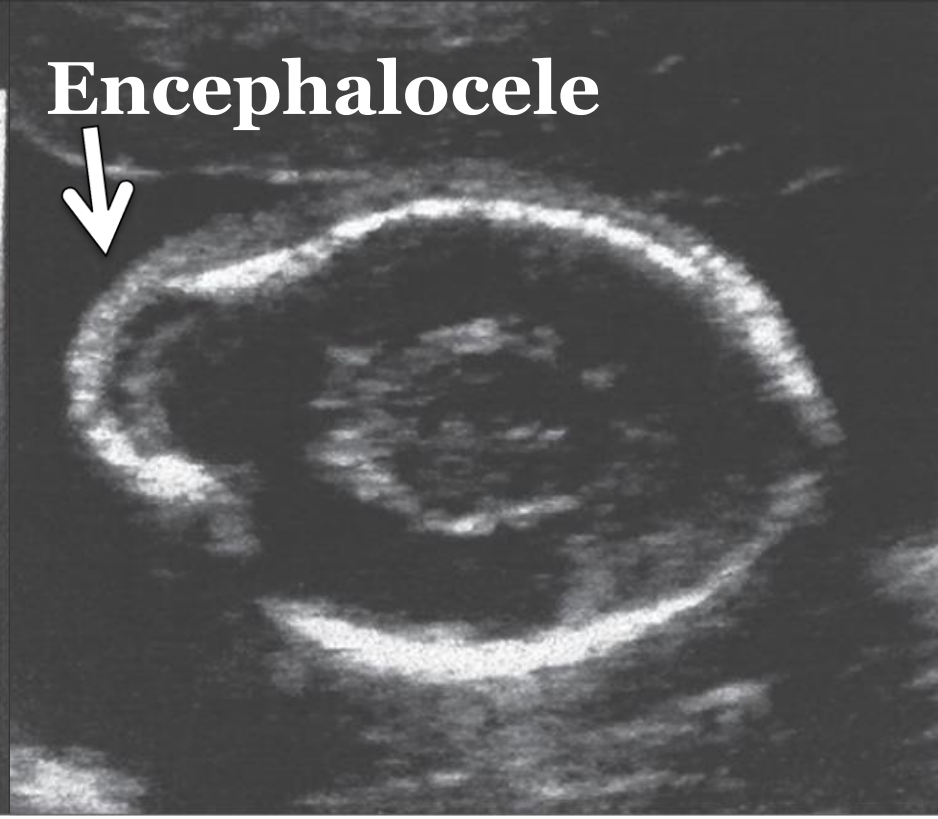
Lobar Holoprosencephaly

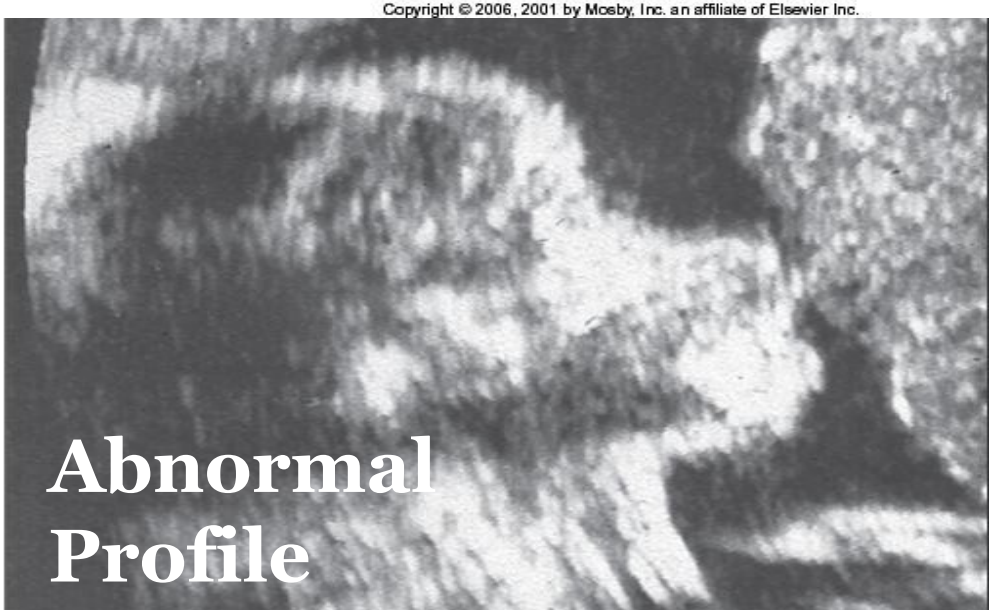
- Almost complete division of the ventricles
- Corpus callosum that may be
  - Normal
  - Hypoplastic
  - Absent
- Cavum septum pellucidum will still be absent

Holoprosencephaly

- **Sonographic findings:**
  - **A common C-shaped ventricle that may or may not be enlarged**
  - **Brain tissue with a horseshoe shape as it surrounds the monoventricle**
  - **Fusion of the thalamus with absence of the third ventricle**
  - **Absence of the interhemispheric fissure**
  - **A dorsal sac with expansion of the monoventricle posteriorly**
  - **Absence of the corpus callosum**
  - **Absence of the cavum septum pellucidum**



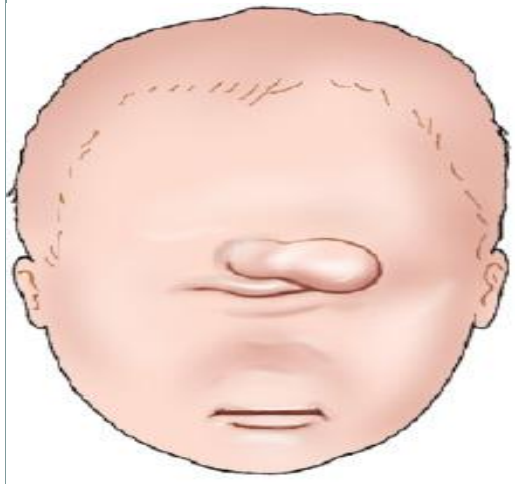




Holoprosencephaly

- Often associated with facial abnormalities
  - Especially with the most severe forms
- Facial anomalies identified include
  - Cyclopia
  - Hypotelorism
  - Absent nose
  - Flattened nose with a single nostril
  - Proboscis

Holoprosencephaly



Cyclopia

Cebocephaly

Ethmocephaly

Lateral facial cleft

Midline facial cleft

Holoprosencephaly

- Other sonographic findings include
  - Hydrocephaly
  - Microcephaly
  - Polyhydramnios
  - IUGR
- In addition
  - Renal cysts or dysplasia
  - Omphalocele
  - Cardiac defects
  - Spina bifida
  - Talipes
  - Gastrointestinal anomalies

Holoprosencephaly

Holoprosencephaly

Proboscis

Agenesis of the Corpus Callosum

- Corpus callosum is a fibrous tract that connects the cerebral hemispheres
- Dysgenesis of the corpus callosum
  - Describes a range of complete to partial absence of the callosal fibers
- Prognosis depends on incidence of associated anomalies; many carry poor prognosis

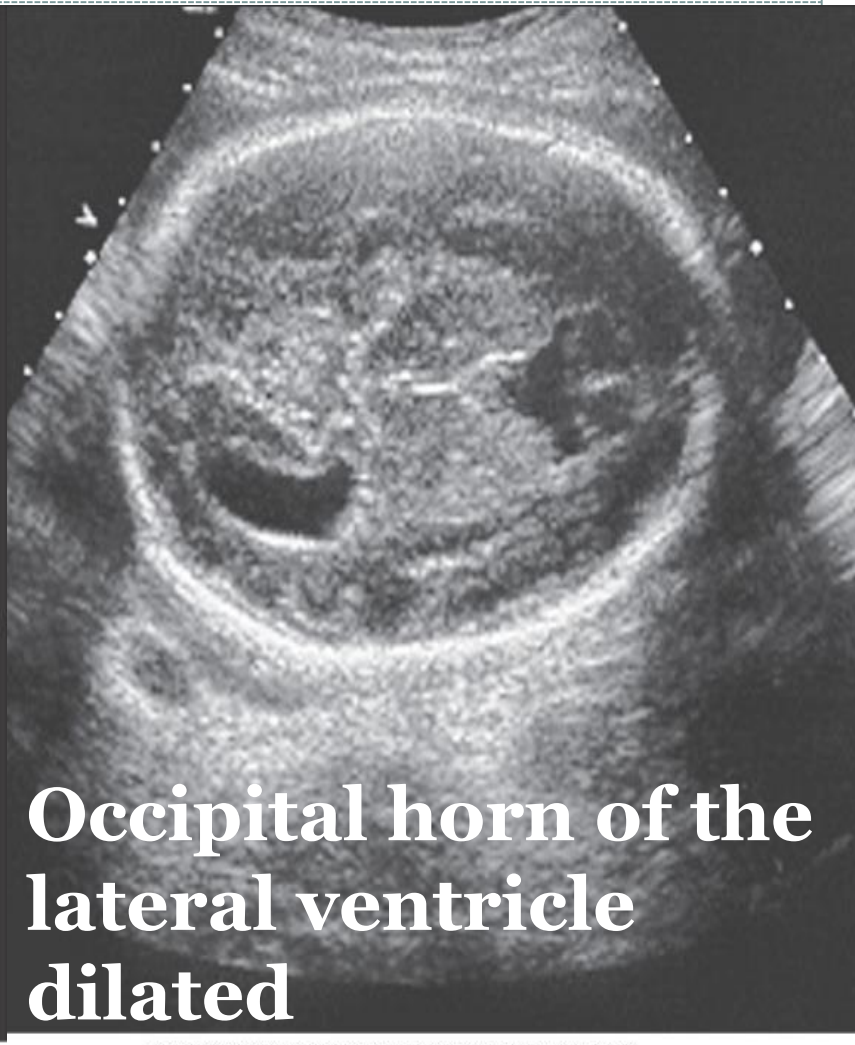
Agenesis of the Corpus Callosum

- Sonographic findings:
  - Absence of the corpus callosum
  - Elevation and dilation of the third ventricle
  - Widely separated lateral ventricular frontal horns with medial indentation of the medial walls
  - Dilated occipital horns (colpocephaly)
    - Giving the lateral ventricles a teardrop shape
  - Absence of the cavum septum pellucidum

Agenesis of the Corpus Callosum

Absent CSP

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



Occipital horn of the lateral ventricle dilated

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

Aqueductal Stenosis

- Results from
  - Obstruction
  - Atresia
  - Stenosis of the aqueduct of Sylvius causing ventriculomegaly
- Aqueduct of Sylvius connects the third and fourth ventricles
  - Explains the enlargement of the lateral ventricles and third ventricle in the presence of a normal fourth ventricle

Aqueductal Stenosis

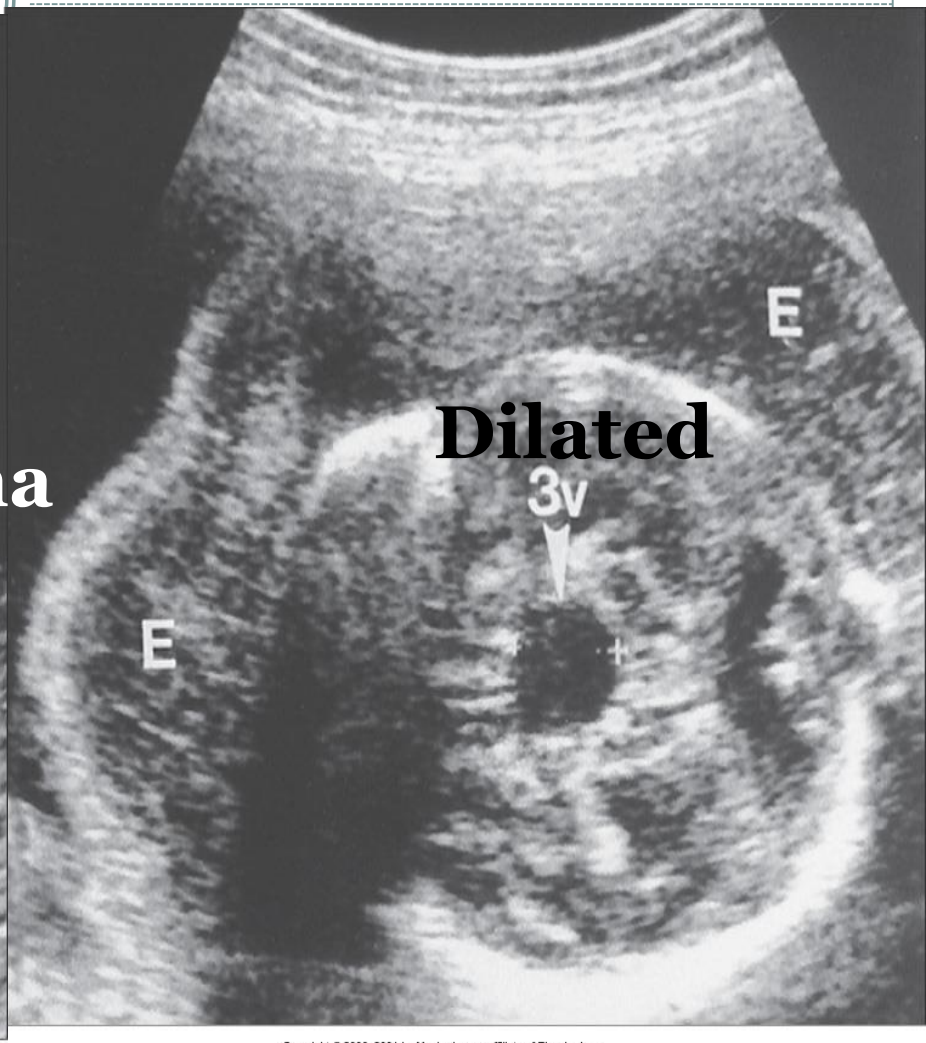
- Usually a sporadic anomaly
- May result from:
  - Intrauterine infections
    - Cytomegalovirus
    - Rubella
    - Toxoplasmosis
- Cranial masses and ventricular hemorrhage are also contributing factors of acquired obstruction

Aqueductal Stenosis

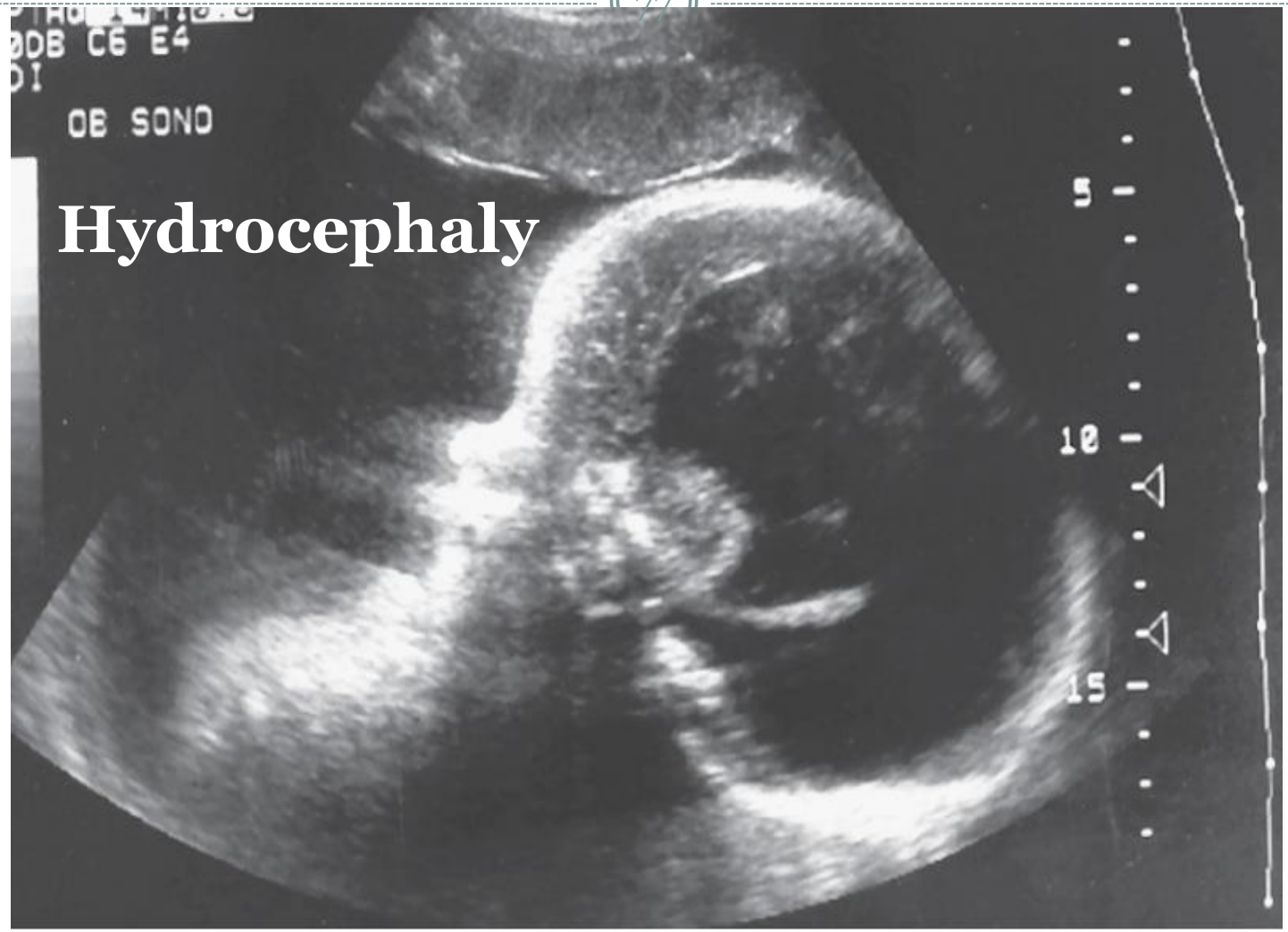
- Sonographic findings:
  - Ventricular enlargement of the lateral ventricles
    - Which may be severe
  - Third ventricular dilation
  - Flexion and adduction of the thumb

Aqueductal Stenosis

Dilation of the ventricular system



Aqueductal Stenosis



Vein of Galen Aneurysm

- Also known as a vein of Galen malformation
- Rare arteriovenous malformation
- Vein is enlarged and communicates with normal-appearing arteries
- Considered a sporadic event and has a male predominance
- Usually an isolated anomaly associated with
  - Congenital heart defects
  - Cystic hygromas
  - Hydrops

Vein of Galen Aneurysm

- **Prognosis is generally poor**
  - **When associated with hydrops and/or cardiac failure**
- **If symptoms present later in older children/young adults, prognosis is generally better**
- **Embolization is primary treatment**

Vein of Galen Aneurysm

- **Sonographic findings:**
  - **A cystic space that may be irregular in shape and is located midline and posterosuperior to the third ventricle**
  - **Turbulent flow with Doppler evaluation**
- **Other sonographic findings include**
  - **Fetal cardiomegaly**
  - **Nonimmune hydrops**
- **Ventriculomegaly with resultant macrocephaly also may develop**

Choroid Plexus Cysts

- Round or ovoid anechoic structures found within the choroid plexus
- Cysts are common and have been identified in approximately 0.4% to 3.6% of antenatal ultrasound examinations
- Choroid plexus cysts contain cerebrospinal fluid and cellular debris that has become trapped with the neuroepithelial folds

Choroid Plexus Cysts

- Usually isolated findings without association with other anomalies
- Often resolve by 22 to 26 weeks of gestation
- Have been identified in association with aneuploidy
  - Most common
    - Trisomy 18
    - Trisomy 21

Choroid Plexus Cysts

- **Sonographic findings:**
  - **Cysts within the choroid plexus ranging in size from 0.3 to 2 cm**
  - **Unilateral or bilateral cysts**
  - **Solitary or multiple**
  - **Unilocular or multilocular**
  - **Enlargement of the ventricle with large cyst**

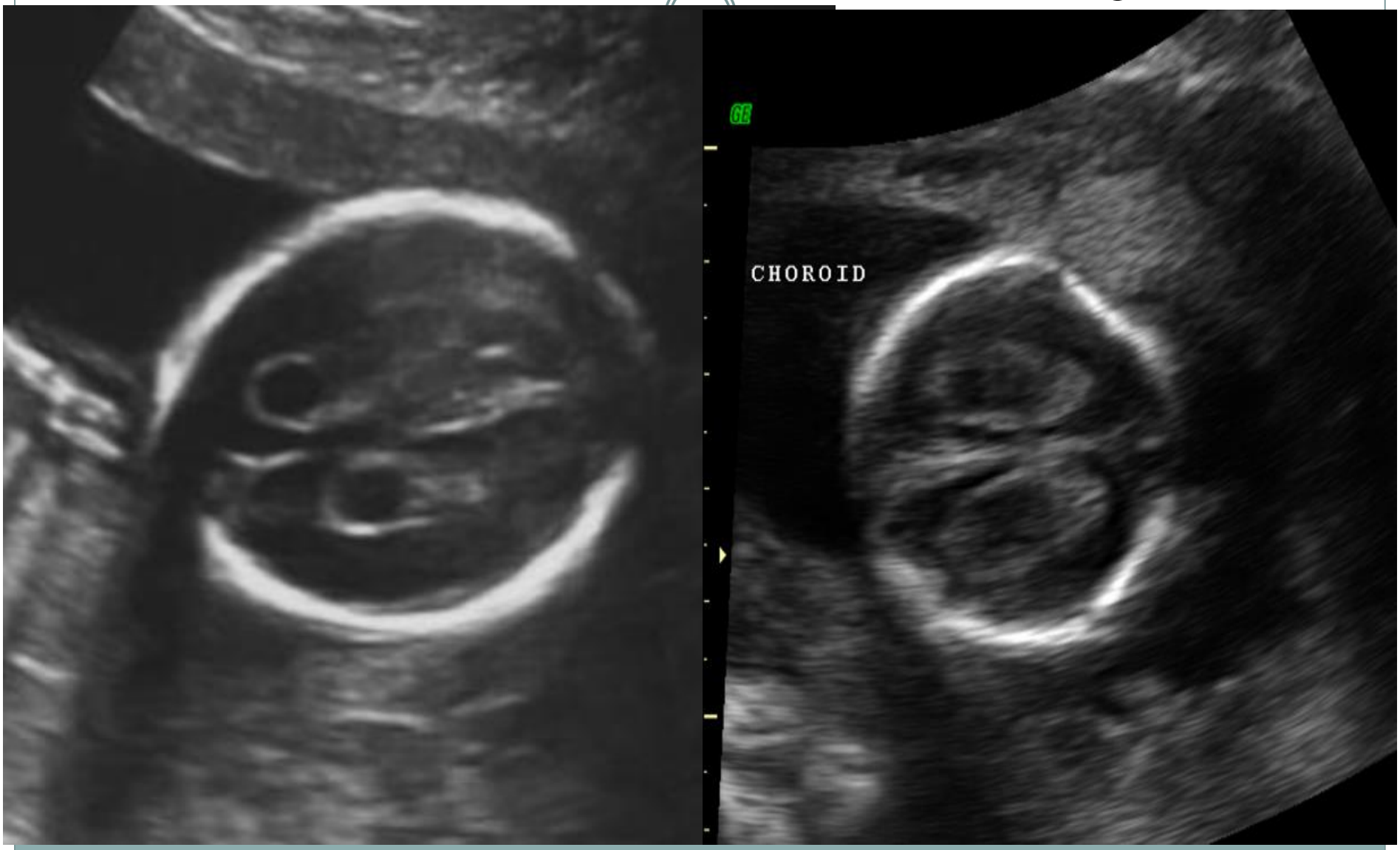
Choroid Plexus Cysts

- Careful sonographic survey for anomalies that might suggest aneuploidy should follow identification of a choroid plexus cyst
  - Should include
    - Nuchal fold measurement
    - Meticulous survey of the heart
    - Survey of the feet and hands to look for abnormal posturing and polydactyly

Choroid Plexus Cysts

- Amniocentesis for karyotyping may be offered
  - When other factors that may increase the risk for aneuploidy are considered including
    - Maternal age
    - Abnormal triple screen
    - Other sonographic findings

Choroid Plexus Cysts



Porencephalic Cysts

- Also known as porencephaly
- Cysts filled with cerebrospinal fluid that communicate with the ventricular system or subarachnoid space
- May result from
  - Hemorrhage
  - Infarction
  - Delivery trauma
  - Inflammatory changes in the nervous system

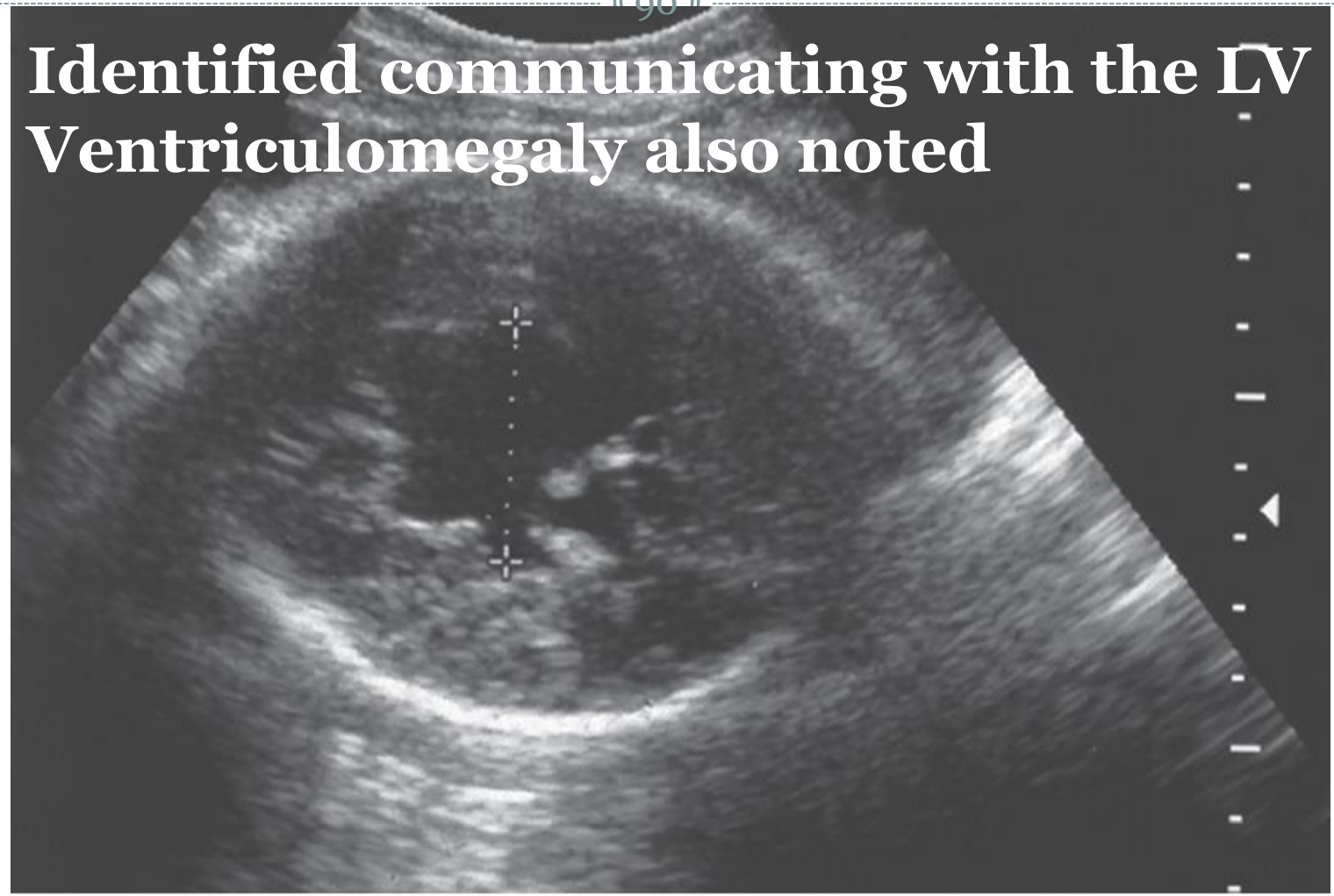
Porencephalic Cysts

- **Sonographic findings:**
  - **Cyst within the brain parenchyma without mass effect**
  - **Communication of the cyst with the ventricle or subarachnoid space**
  - **Reduction in size of the affected hemisphere**
    - **May cause a midline shift and contralateral ventricular enlargement**

Porencephalic Cysts

- **Postnatal problems may include:**
  - **Seizures**
  - **Developmental delays**
  - **Mental deficits**
  - **Visual and sensory problems**
  - **Hydrocephalus**

Porencephalic Cysts



Hydranencephaly

- **Destruction of the cerebral hemispheres by occlusion of the internal carotid arteries**
- **Brain parenchyma is destroyed and is replaced by cerebrospinal fluid**
- **Because the posterior communicating arteries are preserved**
  - **Midbrain and cerebellum are present**
  - **Basal ganglia, choroid plexus, and thalamus also may be spared**

Hydranencephaly

- May be associated with polyhydramnios
- Etiology usually involves congenital infection or ischemia
  - Infections include
    - Cytomegalovirus
    - Toxoplasmosis
- Brain ischemia may result from
  - Maternal hypotension
  - Twin-to-twin embolization
  - Vascular agenesis

Hydranencephaly

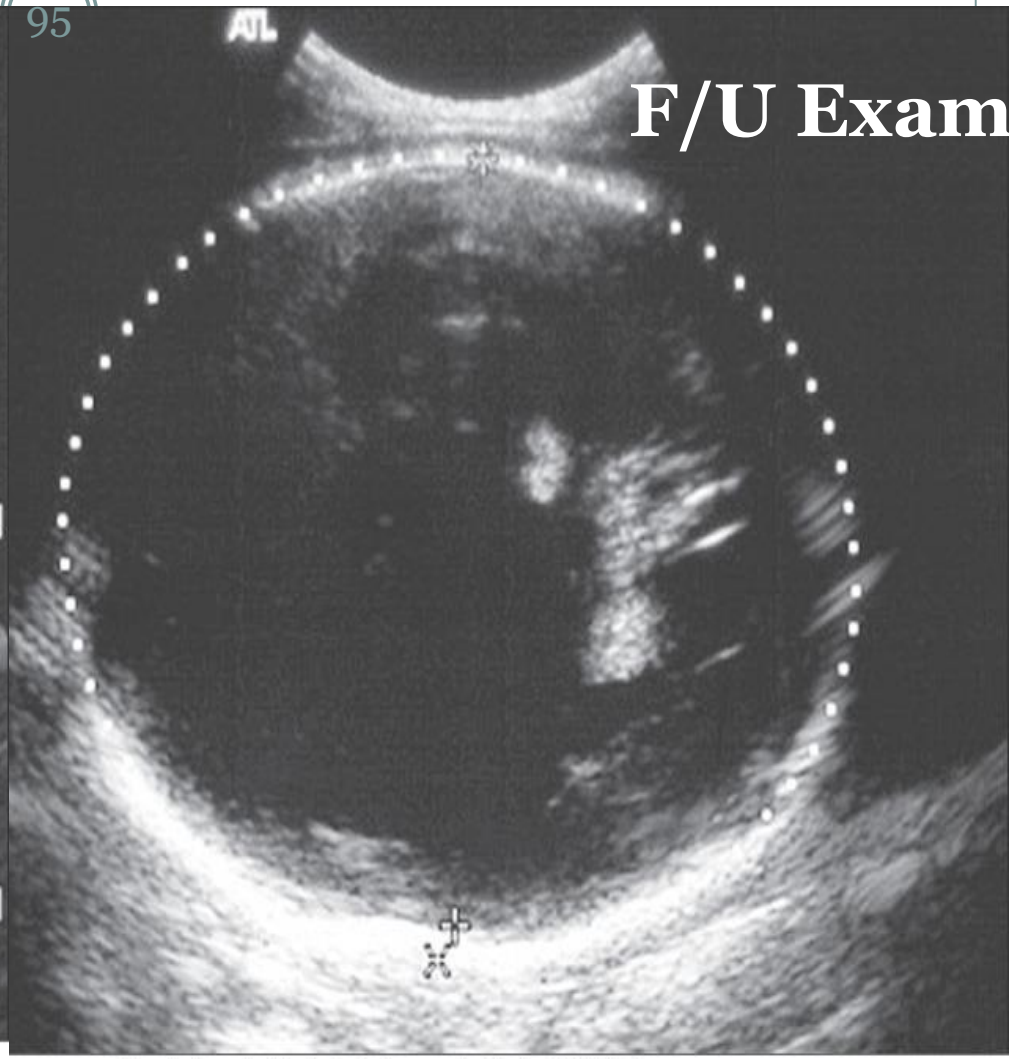
- It is believed that hydranencephaly may occur later in pregnancy and that brain structures initially may be normal
- Assault to the brain by infection or ischemic event subsequently destroys normal brain tissue
- Prognosis is grave
  - Death occurring at birth or shortly thereafter

Hydranencephaly

- **Sonographic findings:**
  - **Absence of normal brain tissue with almost complete replacement by cerebrospinal fluid**
  - **Absent or partially absent falx**
  - **Presence of the midbrain, basal ganglia, and cerebellum**
  - **Choroid plexus may be identified**
  - **Macrocephaly may occur**

Hydranencephaly

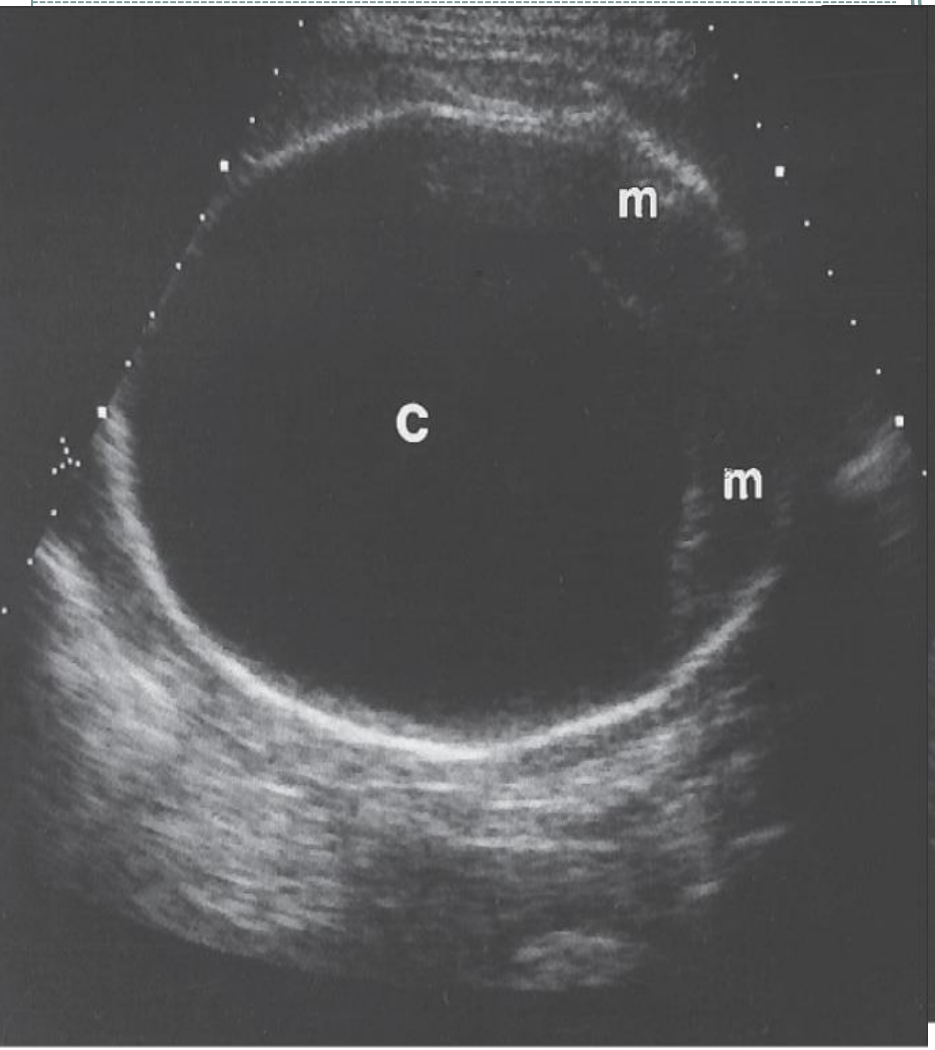
(From Henningsen C: *Clinical guide to ultrasonography*, St Louis, 2004, Mosby.)

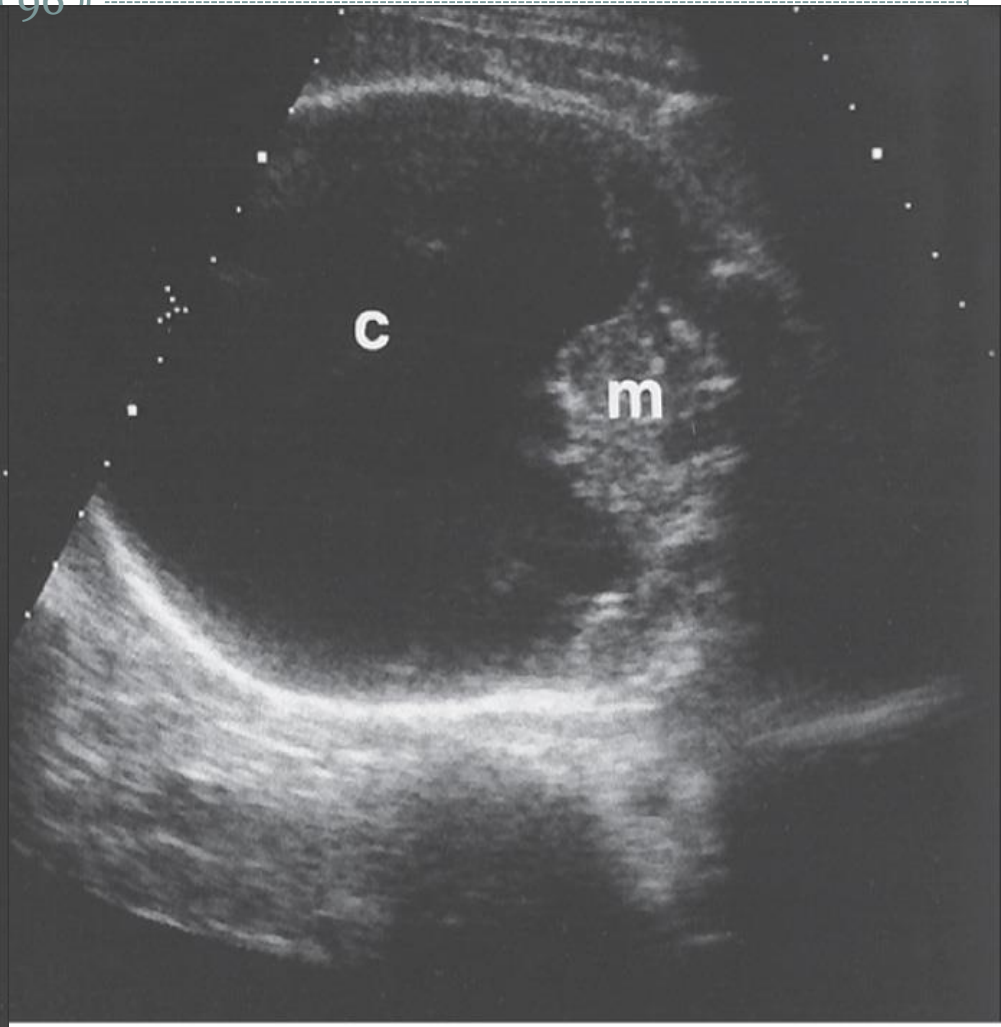


F/U Exam

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

Hydranencephaly





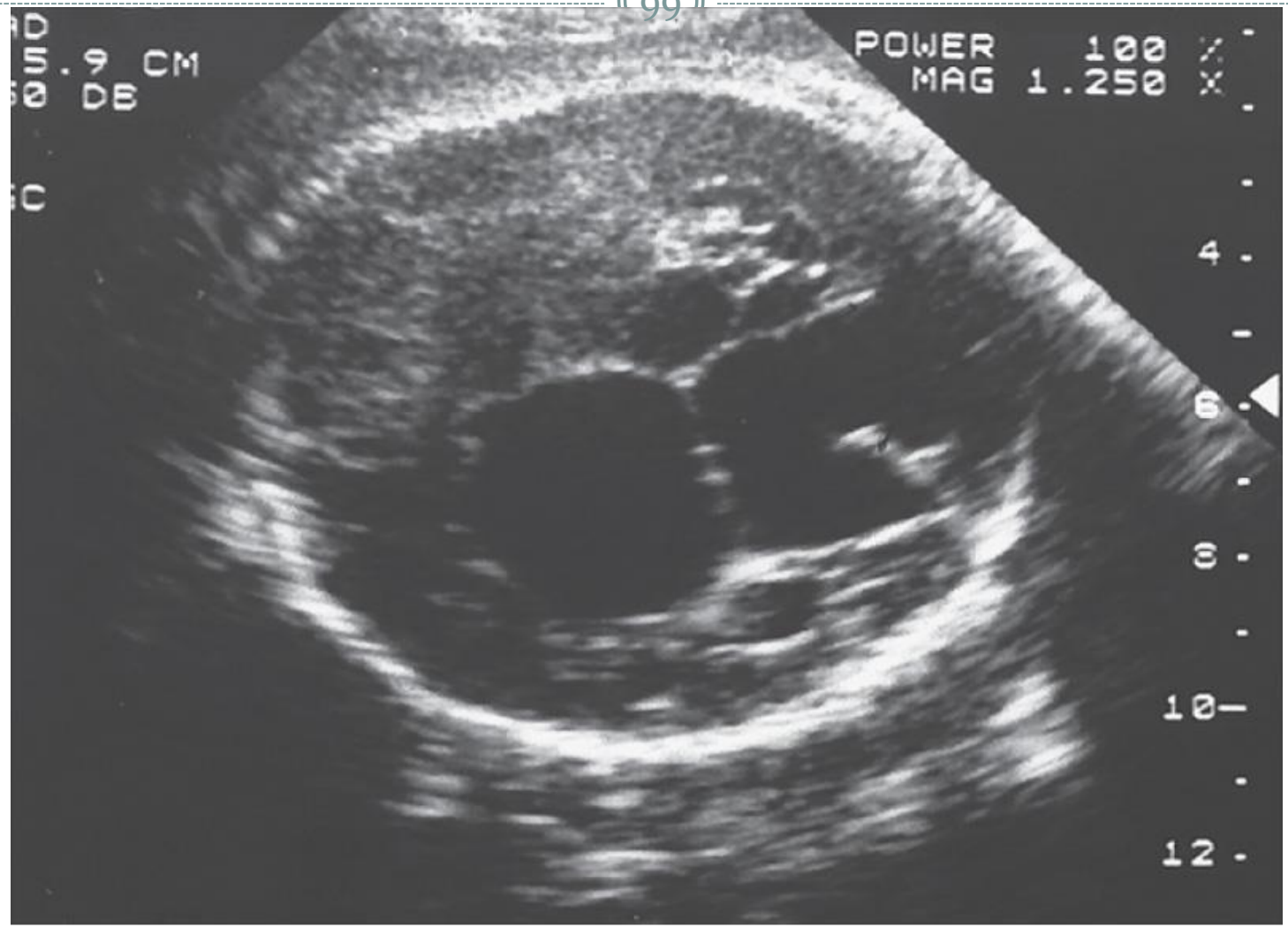
Ventriculomegaly (Hydrocephalus)

- Refers to dilation of the ventricles within the brain
- Hydrocephalus occurs when ventriculomegaly is coupled with enlargement of the fetal head
- Incidence 0.3 to 1.5 per 1000 births

Ventriculomegaly

- Enlargement of the ventricles occurs with obstruction of cerebrospinal fluid flow
- Obstruction may be caused by a ventricular defect
  - Aqueductal stenosis (referred to as noncommunicating hydrocephalus)
- Obstruction may be outside of the ventricular system
  - Arachnoid cyst (referred to as communicating hydrocephalus)

Arachnoid Cysts



Ventriculomegaly

- Rarely results from an overproduction of cerebrospinal fluid by a choroid plexus papilloma
- When an obstruction occurs ventricles dilate as the flow of cerebrospinal fluid is blocked
- Increases the pressure within the ventricular system
  - Leads to ventricular expansion

Ventriculomegaly

- Enlarged ventricles put pressure brain tissue
  - Producing irreversible brain damage
- May be associated with
  - An anomaly
  - Cause may remain unknown
- Common causes include
  - Spina bifida
  - Encephaloceles

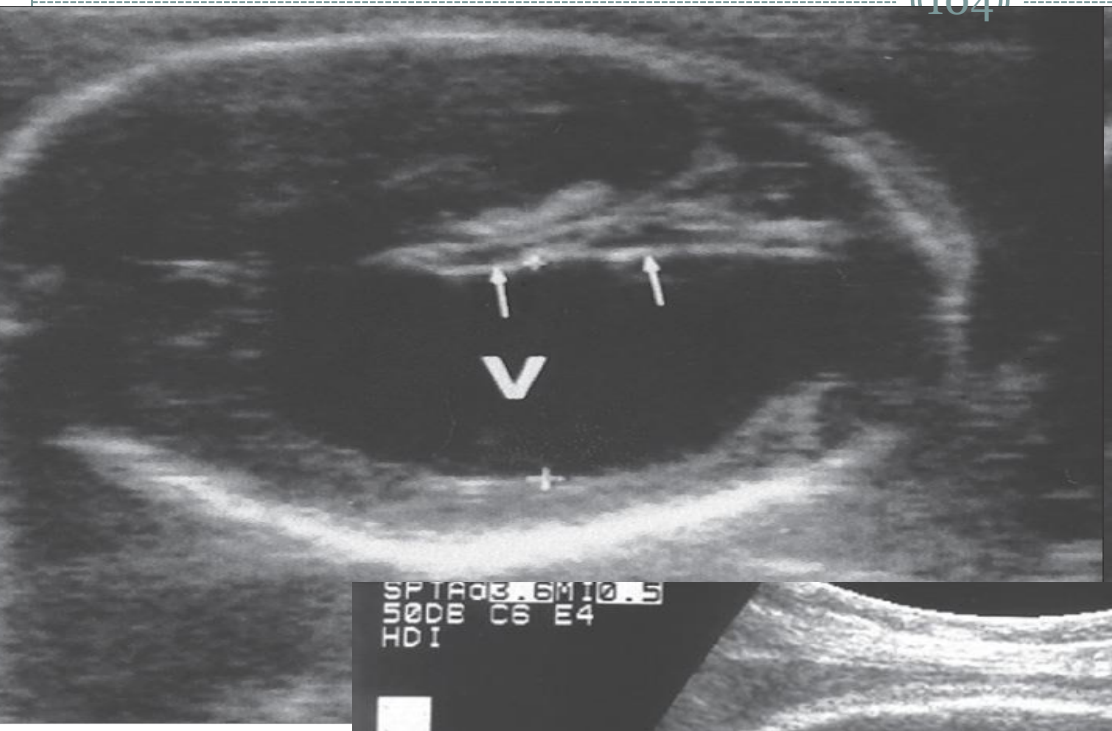
Ventriculomegaly

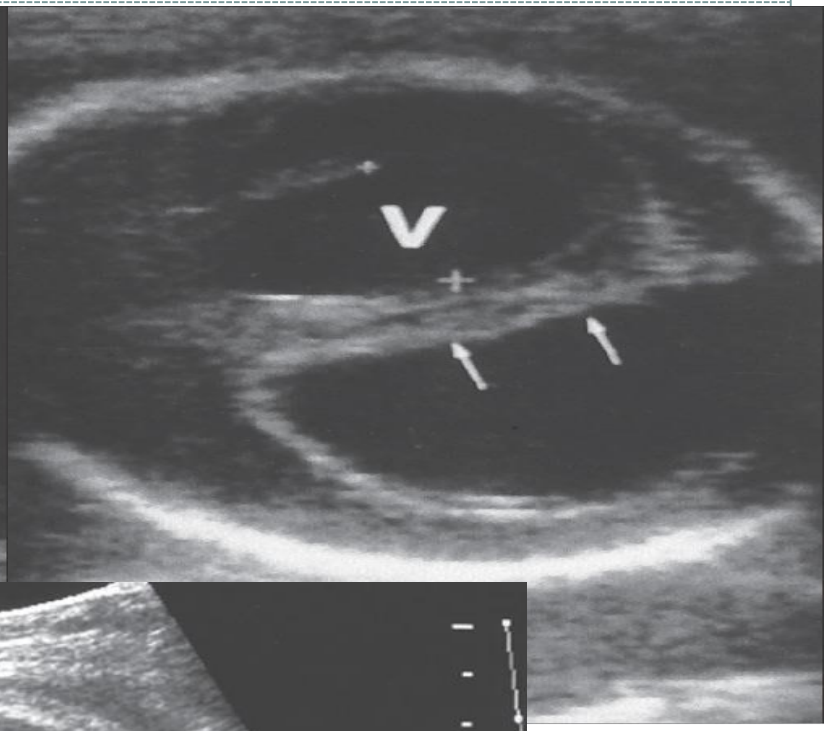
- Mortality rate for hydrocephalus is high
- Outcome depends on severity of associated anomalies
  - Prognosis generally poor
    - Only half have normal intelligence
- Survivors may require ventricular shunting
  - Improves survival and intellectual outcome

Ventriculomegaly

- **Sonographic findings:**
  - **Lateral ventricular enlargement exceeding 10 mm**
  - **A "dangling choroid sign" as the gravity-dependent choroid plexus falls into the increased ventricular space**
  - **Possible dilation of the third and fourth ventricles**
  - **Fetal head enlargement when the biparietal and head circumference measurements exceed those for the established gestational age**

Ventriculomegaly





Microcephaly

- Abnormally small head that falls 3 (textbook states 2) standard deviations below the mean
- Occurs because the brain is reduced in size
- Occurs in 1 per 1000 births
  - More commonly caused by an associated anomaly

Microcephaly

- May result from inheritance of either
  - Autosomal-dominant
  - Autosomal-recessive pattern
- Prognosis depends somewhat on the cause
- About 85% are mentally retarded
- Sonographic diagnosis depends on an accurate assessment of fetal age

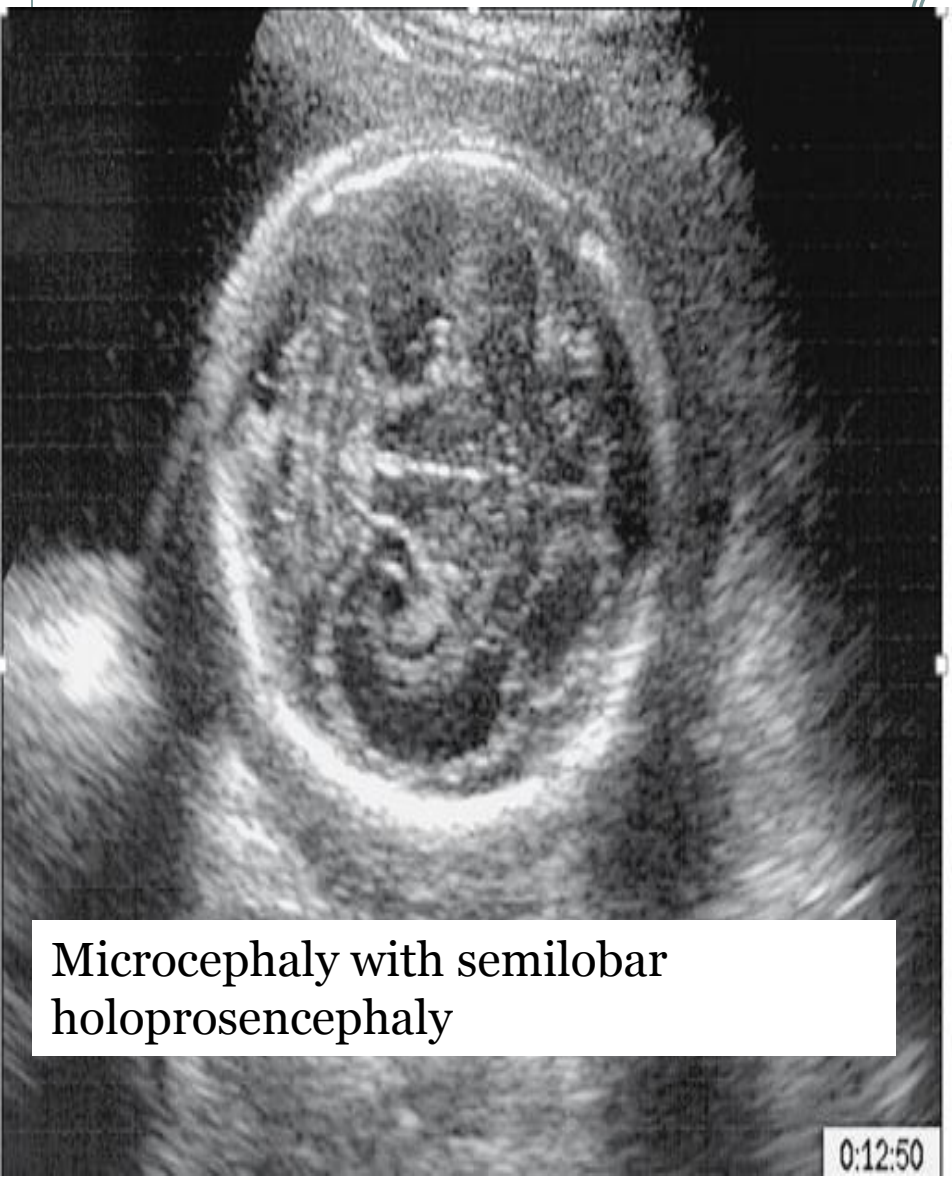
Microcephaly

- **Measurements that should be used**
  - **BPD**
  - **OFD**
  - **HC**
- **In addition ratios to use**
  - **HC/AC**
  - **HC/FL**

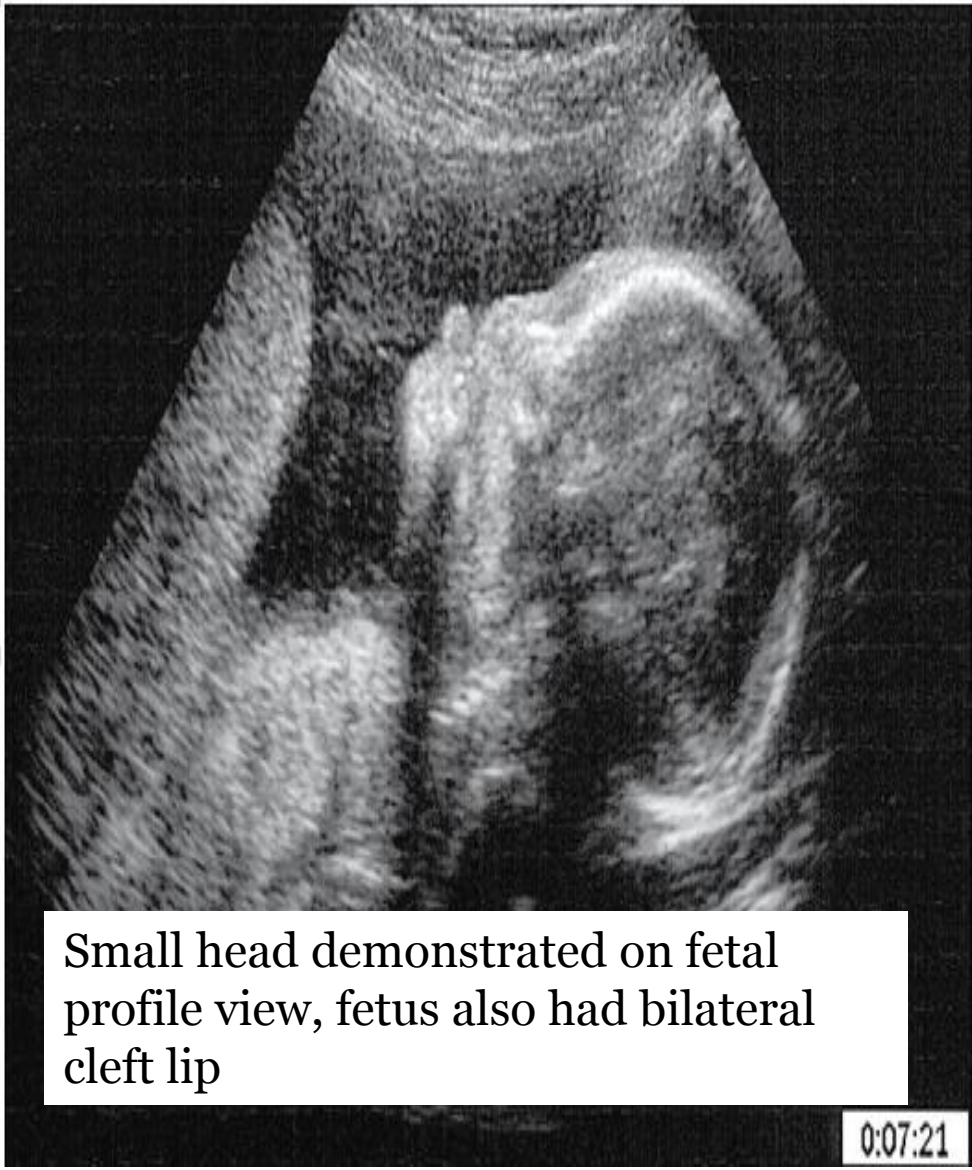
Microcephaly

- **Sonographic findings:**
  - **Small BPD**
  - **Small HC**
  - **Abnormal HC/AC**
  - **Abnormal HC/FL**

Microcephaly



Microcephaly with semilobar holoprosencephaly



Small head demonstrated on fetal profile view, fetus also had bilateral cleft lip

Lissencephaly

- Smooth brain surface
  - Absence of sulci and gyri
- Difficult to diagnose – not seen until later in third trimester
- Associated with:
  - Ventriculomegaly
  - Agenesis of corpus callosum
  - Dandy-Walker malformation
  - Colpocephaly

Lissencephaly

Lissencephaly