Neonatal and Infant Spine

Chapter 29

Objectives:

- Describe the normal anatomy of the vertebral column and spinal cord
- Identify the indications for ultrasound of the spine
- Discuss the sonographic evaluation of the spine
- Recognize pathology of the neonatal and infant spine

Anatomy of the Vertebral Column and Spinal Cord

Anatomy

- Vertebral column consists of 33 vertebrae: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused to form the sacrum), and 4 coccygeal fused bones

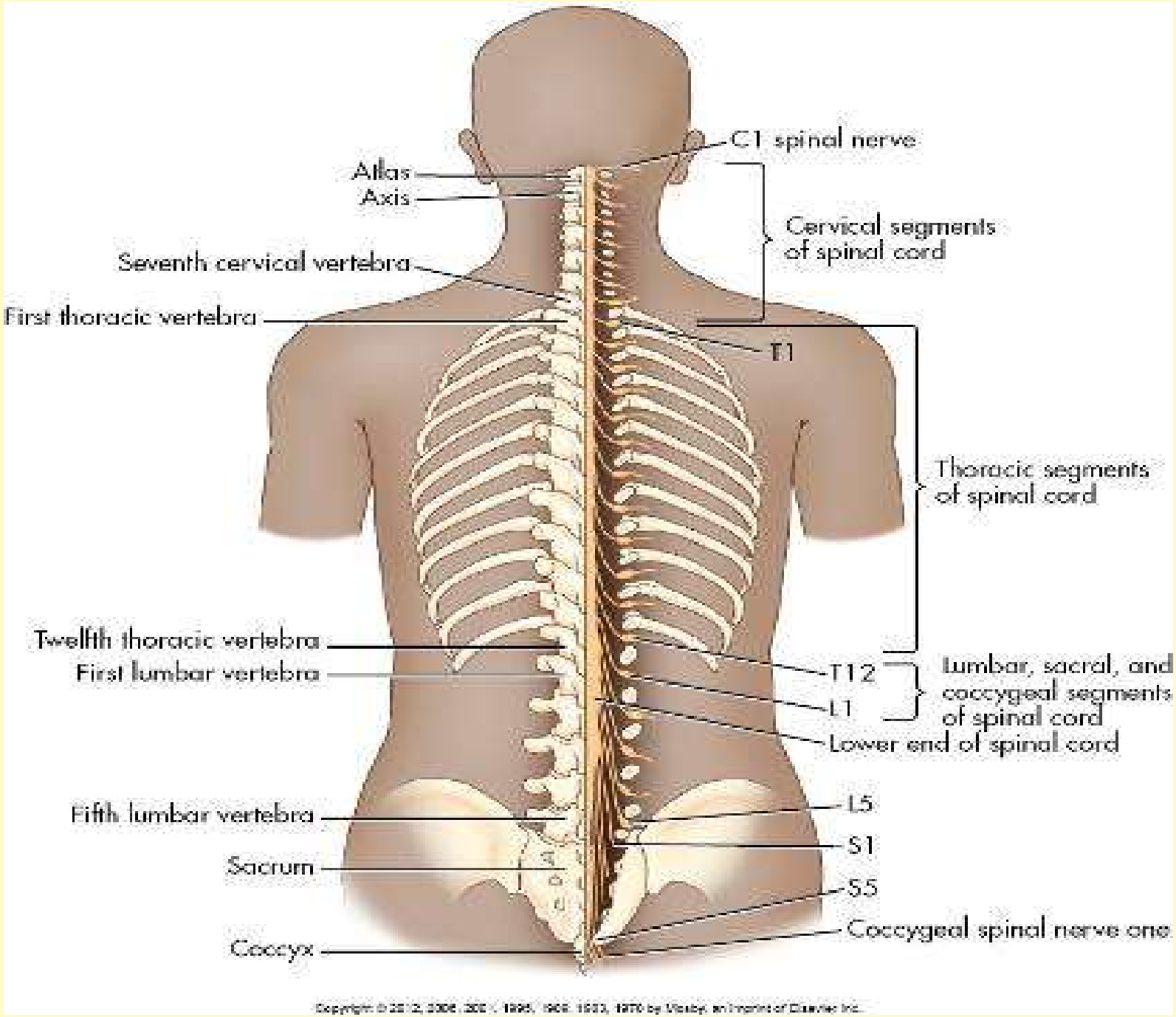
- Pads of fibrocartilage called intervertebral disks are found between each vertebra and allow flexibility in the spine

Anatomy (cont'd)

- An enclosed space, called vertebral foramen, through which runs the spinal cord and its coverings
- Vertebral arch consists of pair of cylindrical pedicles, which form the sides of the arch, and a pair of flattened laminae, which complete arch posteriorly
- Vertebral arch gives rise to seven processes: one spinous, two transverse, four articular
- Two superior articular processes of one vertebral arch articulate with two inferior articular processes of the arch above, forming two synovial joints

Anatomy (cont'd)

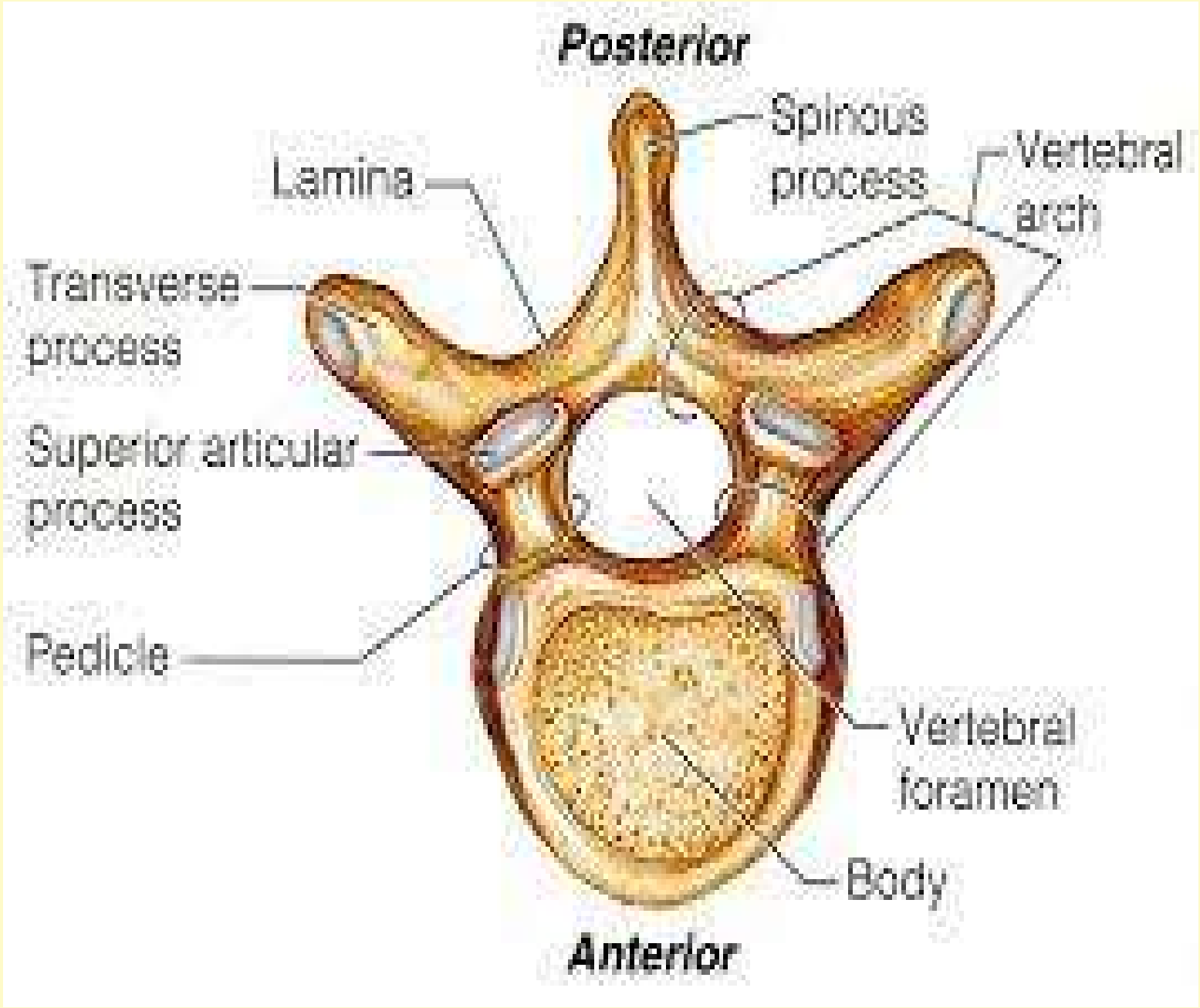
- Pedicles are notched on their upper and lower borders, forming superior and inferior vertebral notches
- On each side, superior notch of one vertebra and inferior notch of adjacent vertebra together form intervertebral foramen
- Foramina serve to transmit spinal nerves and blood vessels
- In neonate, problems typically occur in lower back near area of lumbar vertebrae and sacrum


C1 spinal nerve
Atlas
Axis
Cervical segments of spinal cord
Seventh cervical vertebra
First thoracic vertebra
T1
Thoracic segments of spinal cord
Twelfth thoracic vertebra
First lumbar vertebra
T12
L1
Lumbar, sacral, and coccygeal segments of spinal cord
Lower end of spinal cord
Fifth lumbar vertebra
L5
S1
Sacrum
S5
Coccygeal spinal nerve one
Coccyx

Anatomy (cont'd)

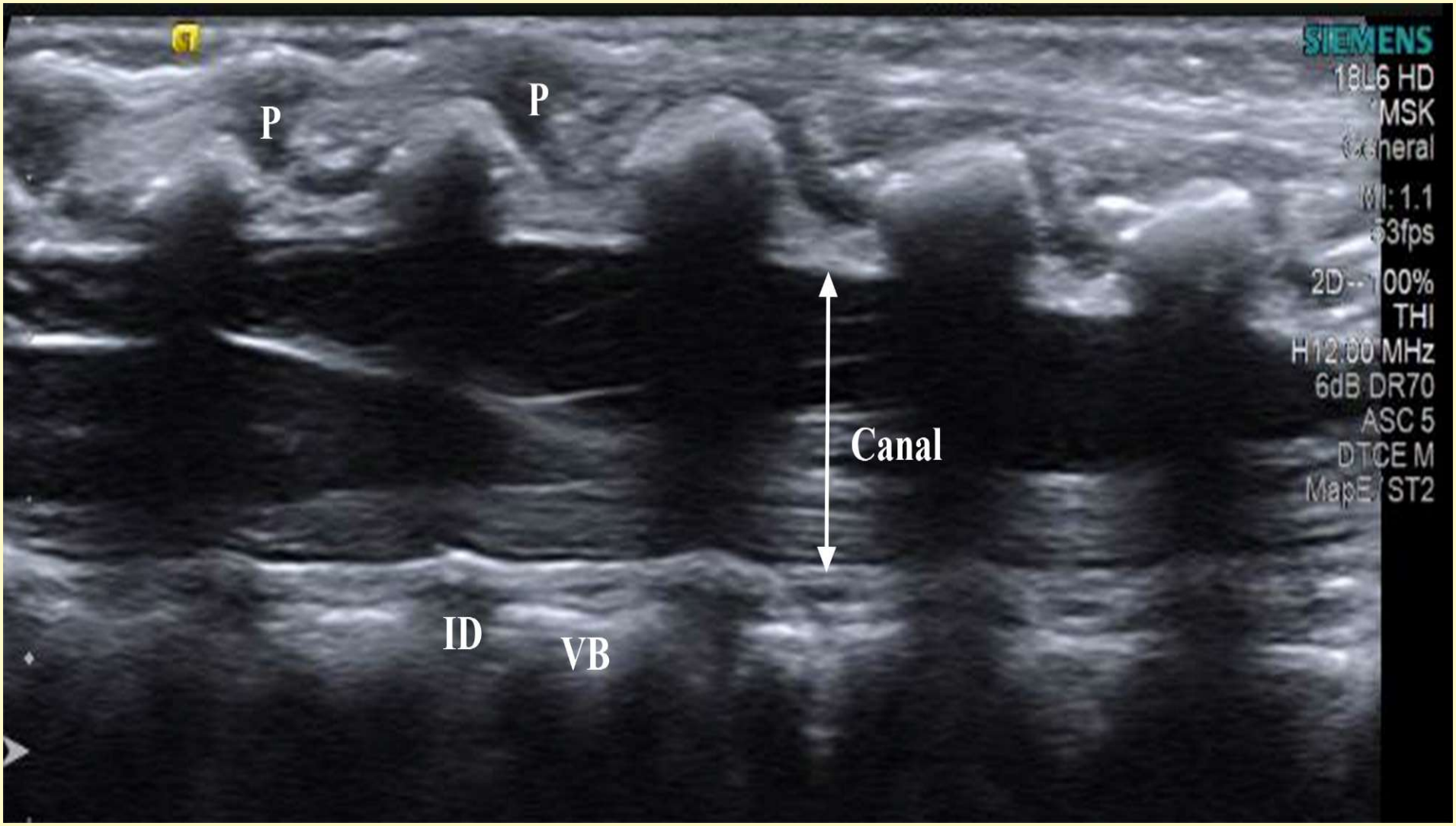
Characteristics of lumbar vertebrae:

- Body: Large and oval
- Pedicles: Strong and directed posterior
- Laminae: Thick
- Vertebral foramina: Triangular
- Transverse processes: Short, flat, quadrangular; project backward
- Articular surfaces of superior articular processes face medially; inferior articular processes face laterally

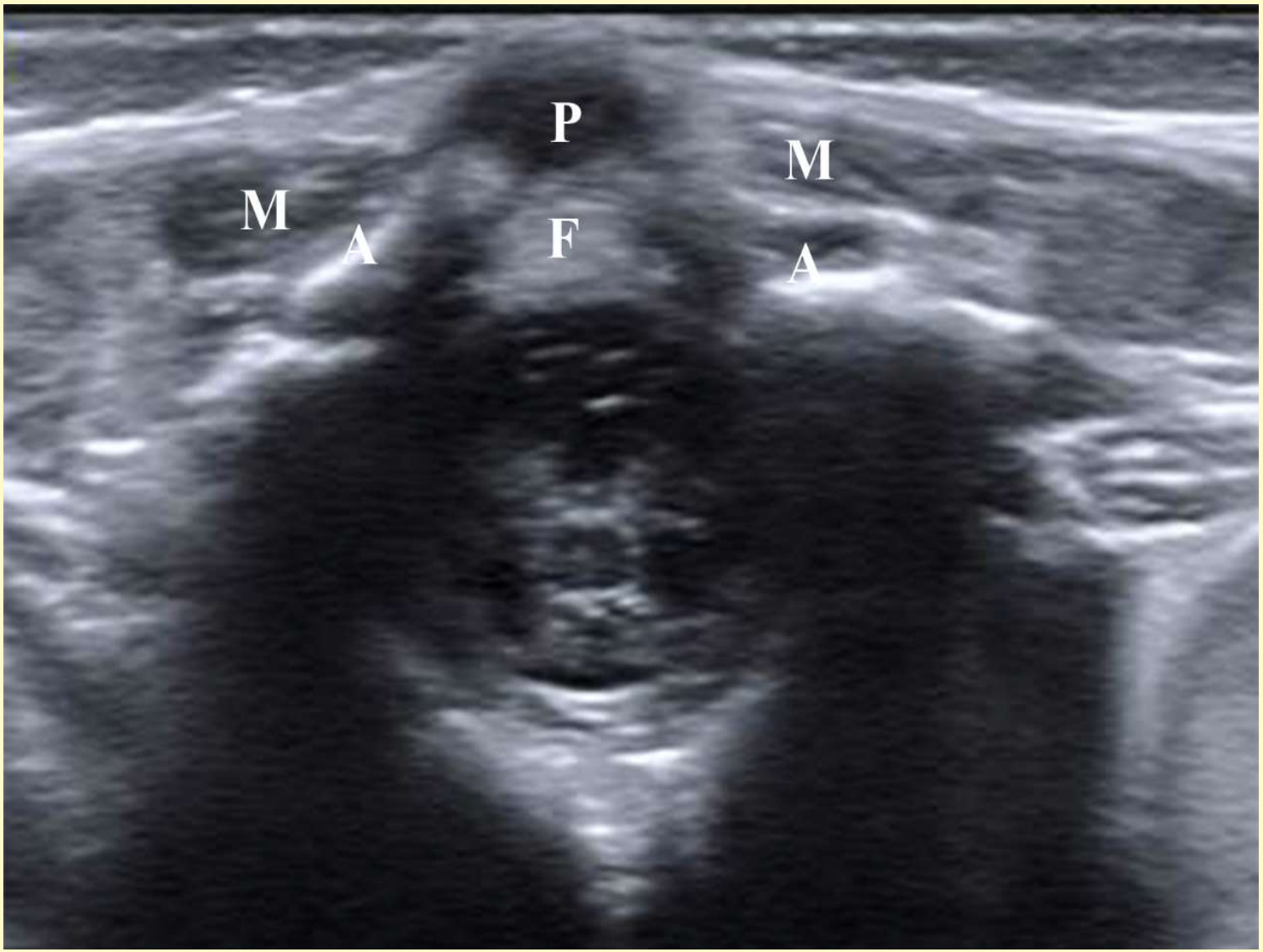

Posterior
Spinous process
Lamina
Vertebral arch
Transverse process
Superior articular process
Pedicle
Vertebral foramen
Body
Anterior

Anatomy (cont'd)

- Sonography is performed from the back, the anterior vertebral bodies appear echogenic and lie posterior to the hypoechoic spinal canal
- The cartilaginous posterior spinous processes appear hypoechoic, allowing for visualization of the canal when scanning directly over them
- Laminae are seen when scanning slightly off midline and appear similar to overlapping roof tiles



Longitudinal view of normal thoracic/lumbar spine. Vertebral body (VB), intervertebral disks (ID), posterior spinal process (P).

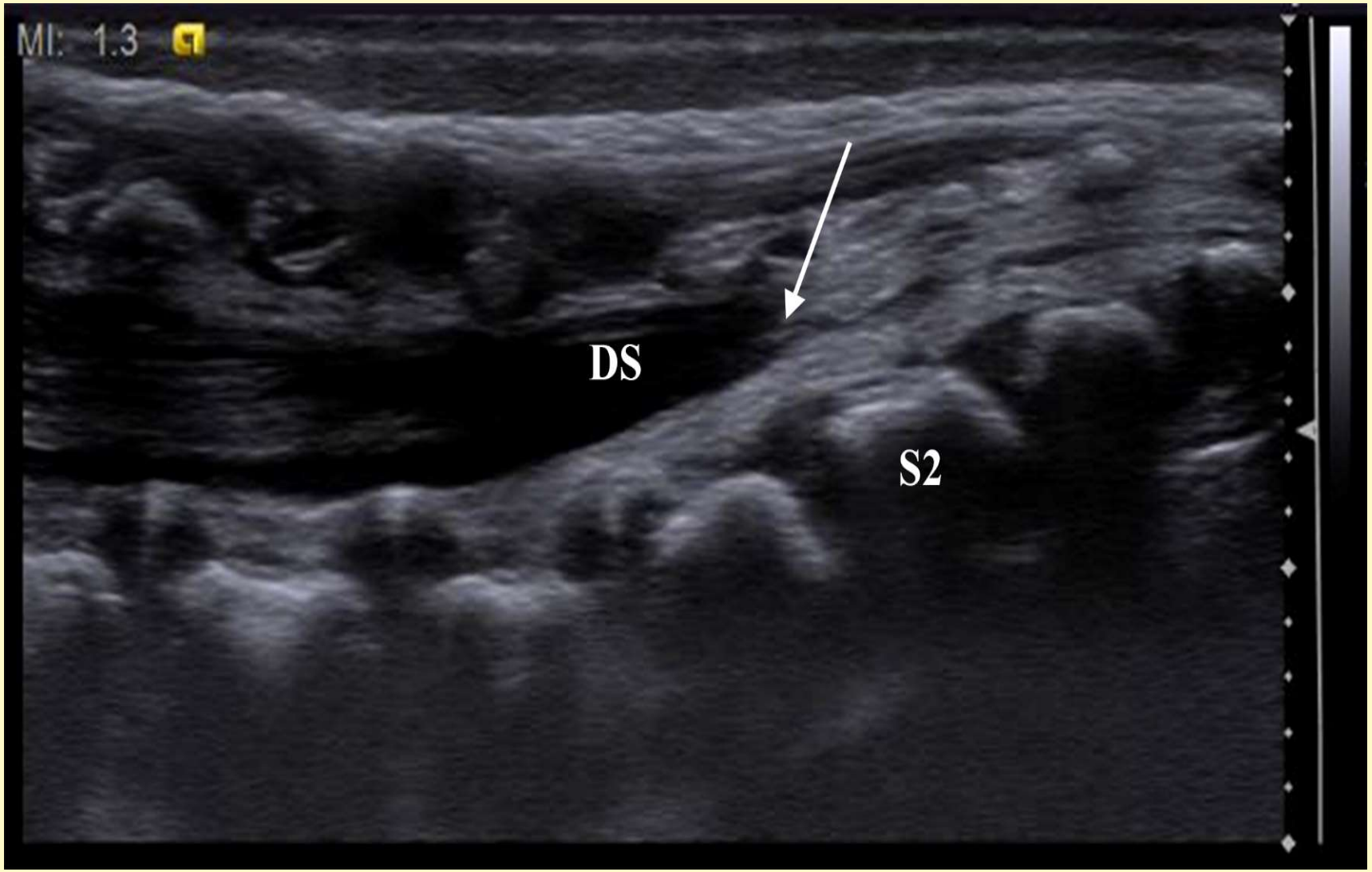


Transverse view of the lumbar spine. Vertebral arch (A), muscle (M), fat (F), posterior spinal process (P)

Anatomy (cont'd)

- Sacrum consists of five bones fused together
- Upper border articulates with fifth lumbar vertebra
- Narrow inferior border articulates with coccyx
- Laterally sacrum articulates with two iliac bones to form sacroiliac joints
- Anterior and upper margin of first sacral vertebra bulges forward as posterior margin of pelvic inlet; known as the sacral promontory

Longitudinal view over the hypoechoic coccyx. Rectum (R) is seen posteriorly.



The dural sac (DS) containing cerebrospinal fluid ends (arrow) at the level of the second sacral bone (S2).

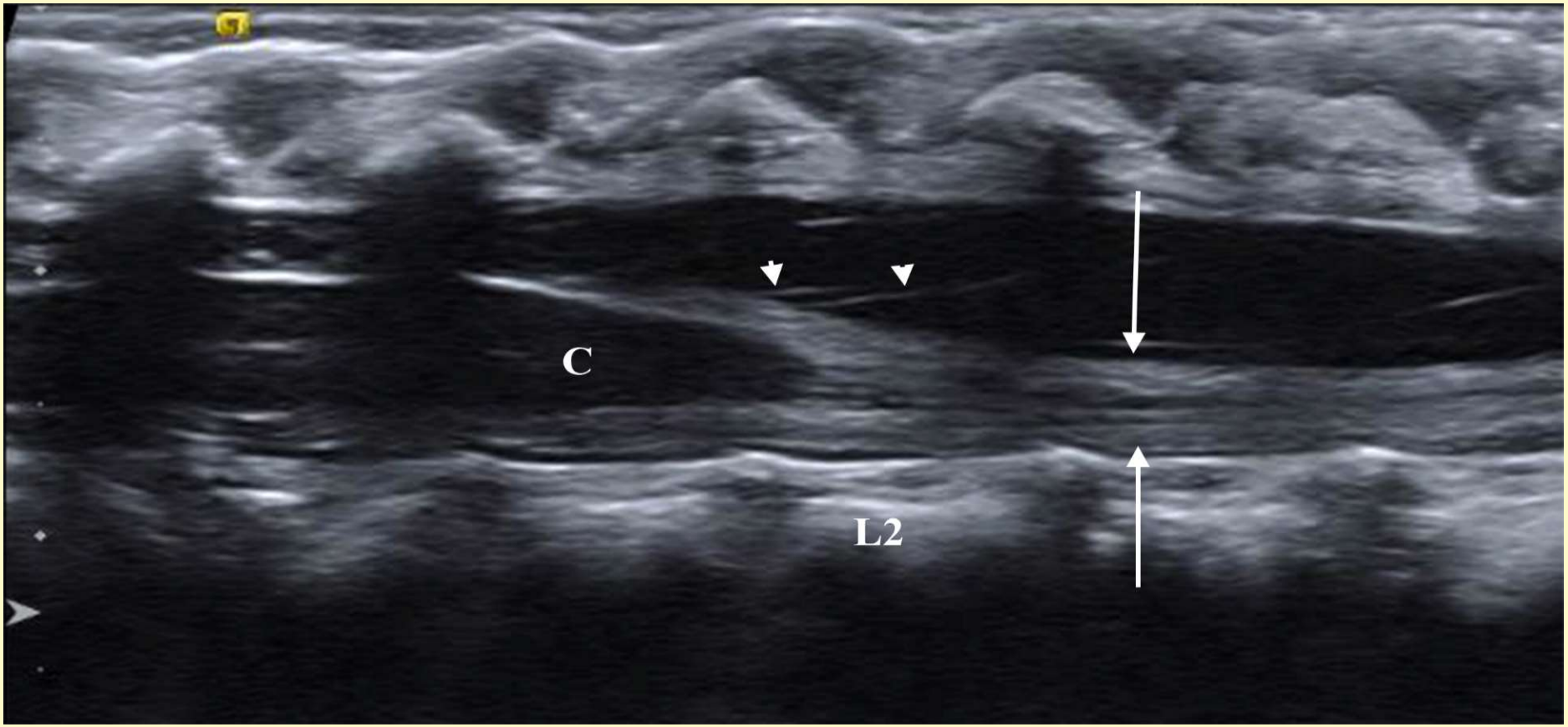
Spinal Cord

- Cylindrical, grayish white structure that begins at foramen magnum, where it is continuous with medulla oblongata of brain
- Terminates below in adult at level of lower border of first lumbar vertebra
- In younger child is relatively longer; ends at upper border of third lumbar vertebra
- Inferiorly tapers off into conus medullaris, from the apex of which a prolongation of the pia mater, the filum terminale, descends to attach to the back of the coccyx

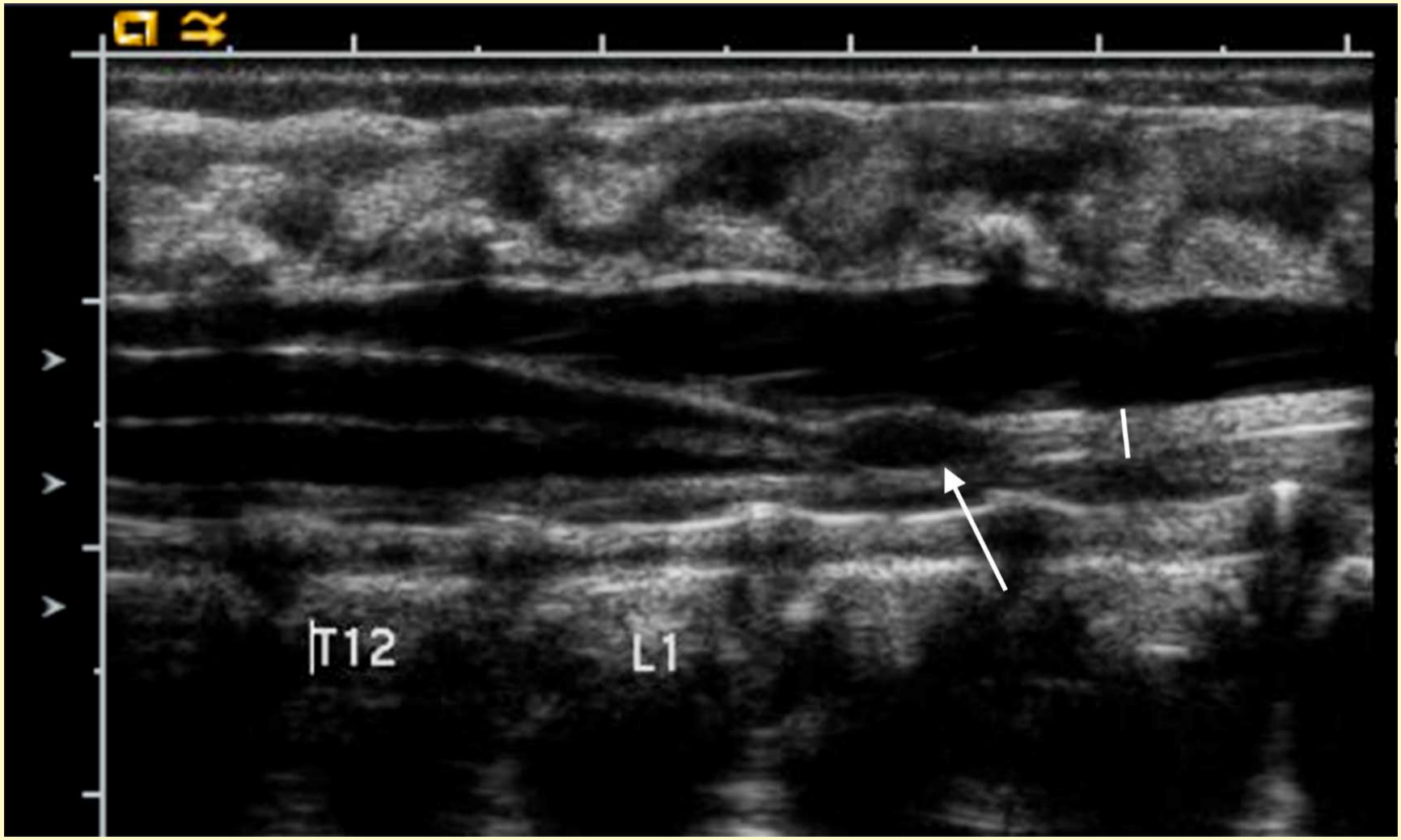
Spinal Cord

- The filum terminale appears echogenic and should measure ≤ 2 mm in thickness

- A normal variant to be aware of is the filar cyst. These small cysts in the filum terminale might be remnants of a terminal ventricle or an arachnoid pseudocyst and have no clinical significance



Tip of the conus medullaris *(C)* should taper gradually. Individual dorsal nerve roots are visible *(short arrows),* along with the cauda equina *(long arrows).*



Normal filar cyst variant *(arrows)* appears as a small anechoic fluid collection seen in the filum, among the nerve roots of the cauda equina, just below the tip of the conus medullaris.

Spinal Nerves

- 31 pairs of spinal nerves are attached along the length of the spinal cord.
- Nerve roots unite to form spinal nerve.
- Lower nerve roots together are called cauda equine

Indications for Sonography

- Occult tethered spinal cord
- Various spinal dysraphic conditions
- Midline cutaneous deformities to spinal canal
- Diagnosis of myelomeningocele or myeloschisis
- Lower extremity deformity

Suspicious Indications

- Dimple along spinal canal greater than 1 inch from anus
  - appears unusually deep or asymmetric
- Hemangioma or raised mid-line area
- Hairy patch
- Tail-like projection from the lower spine

Suspicious Indications

Spinal Dysraphism

- Includes disorders involving absent or incomplete closure of neural tube
- Severity ranges from mild spina bifida occulta to severe spina bifida aperta
- Failure of early recognition may lead to difficulty in walking or other neurologic problems in infancy or childhood

Sonographic Evaluation

Patient Preparation

- Incomplete ossification of posterior spinal elements allows sonography to provide a broad view
- Posterior approach
  - Patient prone or lateral decubitus
  - Upright (against the mother's abdomen) or sitting position
- Crucial for spine to be flexed enough to separate posterior spinal elements
  - Can use small pillow or a rolled towel

Transducer

- Linear
- Curvilinear or sector in some cases
- Highest frequency available
  - 15 MHz – small baby
  - 8 MHz – larger baby

Scan Planes

- Longitudinal
- Transverse

- The longitudinal images are obtained directly over the spine, unless the infant is older and ossification obscures this view, in which case a parasagittal approach is best

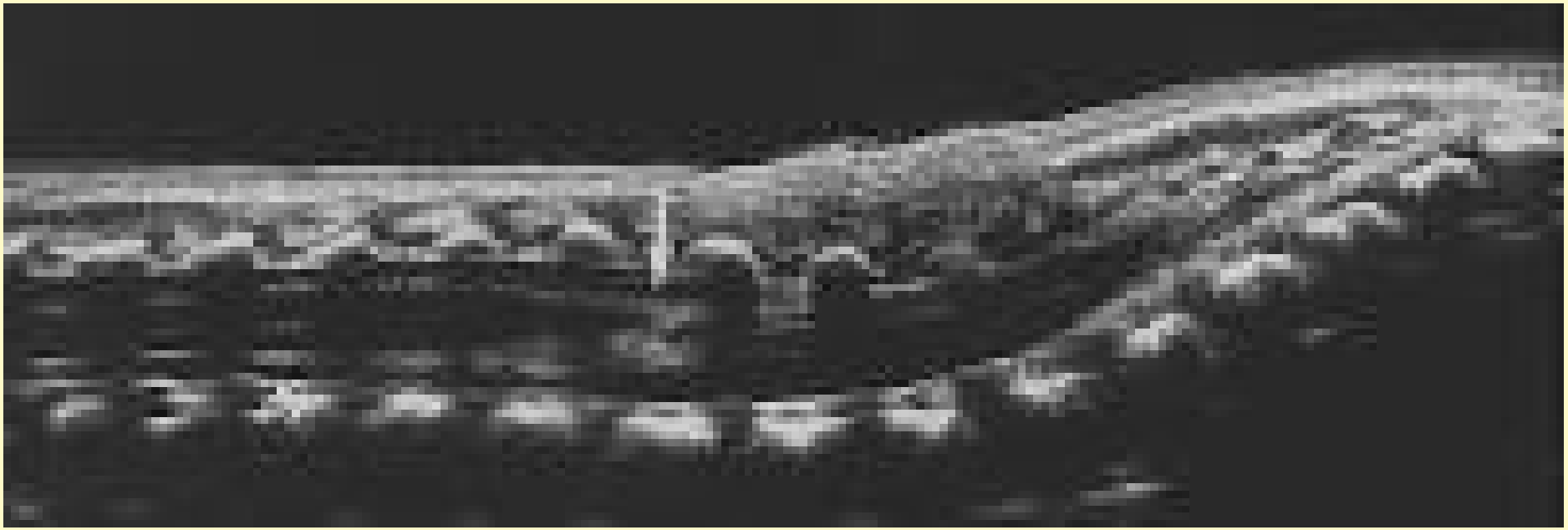
- Transverse images are taken mainly between the spinous processes

- Orientation of the probe is the same as in conventional abdominal imaging

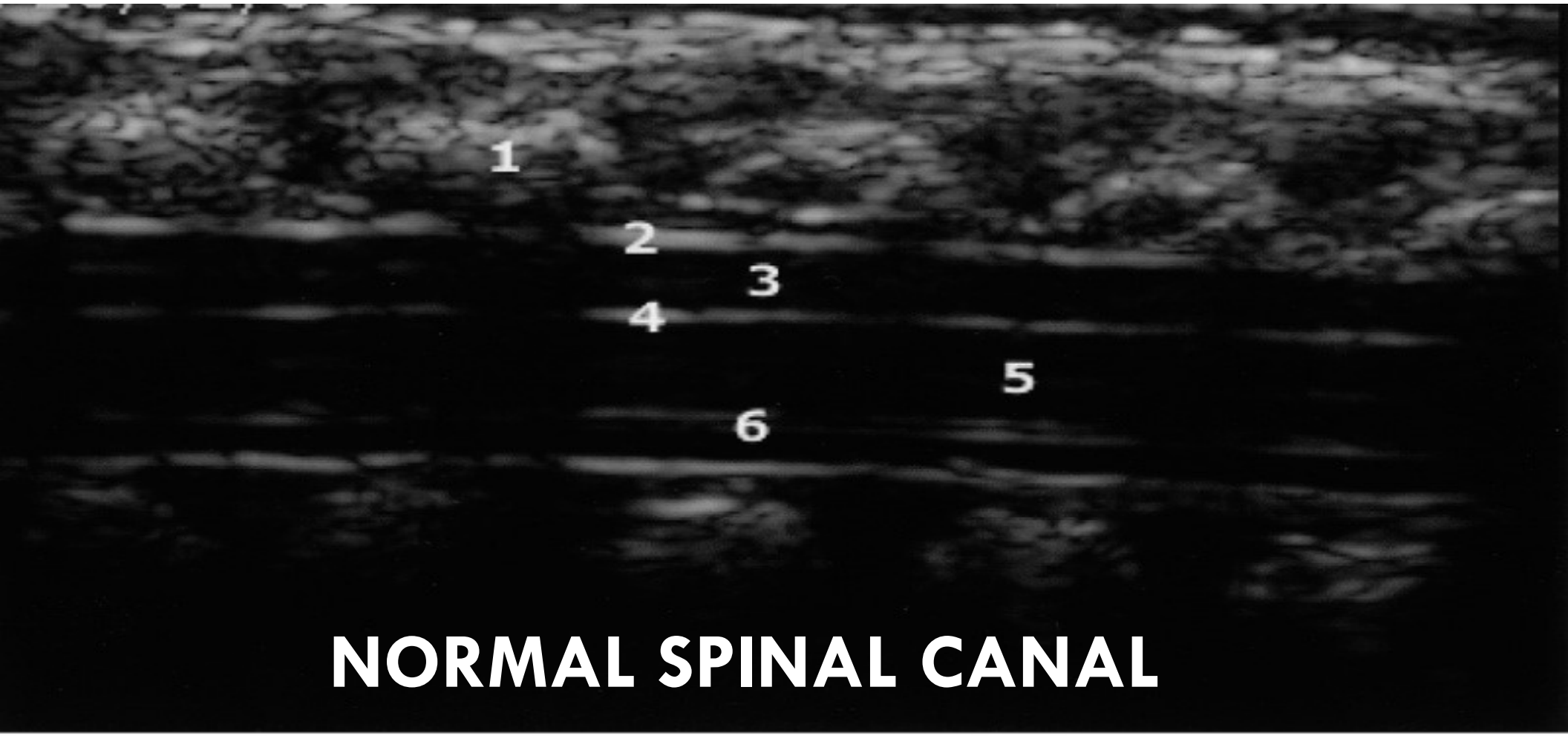
- Stand-off pad may be used to examine the soft tissues

Sonographic Anatomy

- Spinal canal defined anteriorly by echogenic posterior vertebral body and posteriorly by posterior dorsal spinal elements
- Spinal cord is hypoechoic with slightly echogenic borders and an echogenic line extending longitudinally along its midline

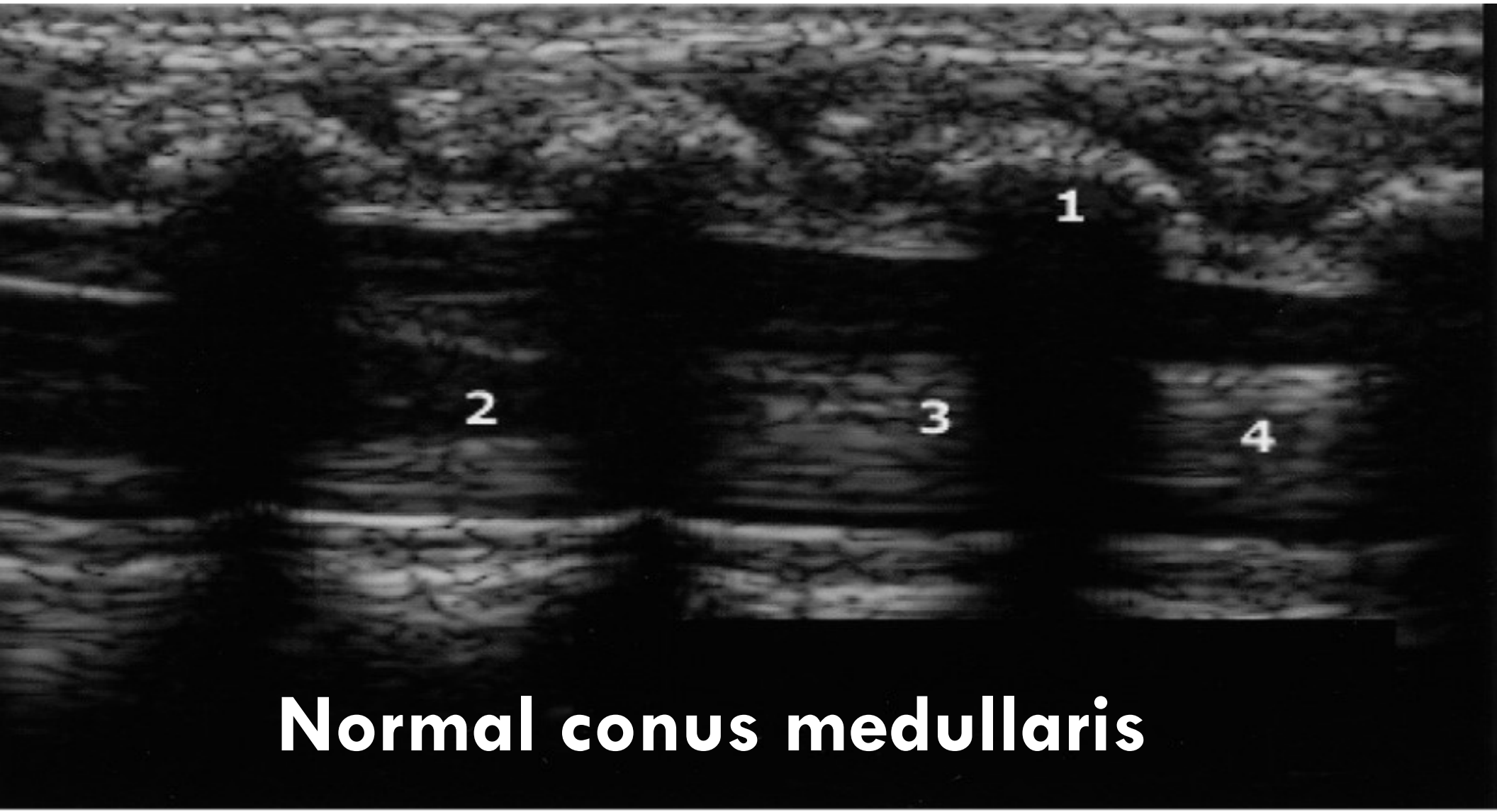


- Dura: Echogenic line just internal to osseous borders.
- Spinous processes appear as inverted “U”’s.
- Laminae seen when scanning slightly off midline; they look like overlapping roof tiles.
- Coccyx: Mostly or completely unossified and hypoechoic



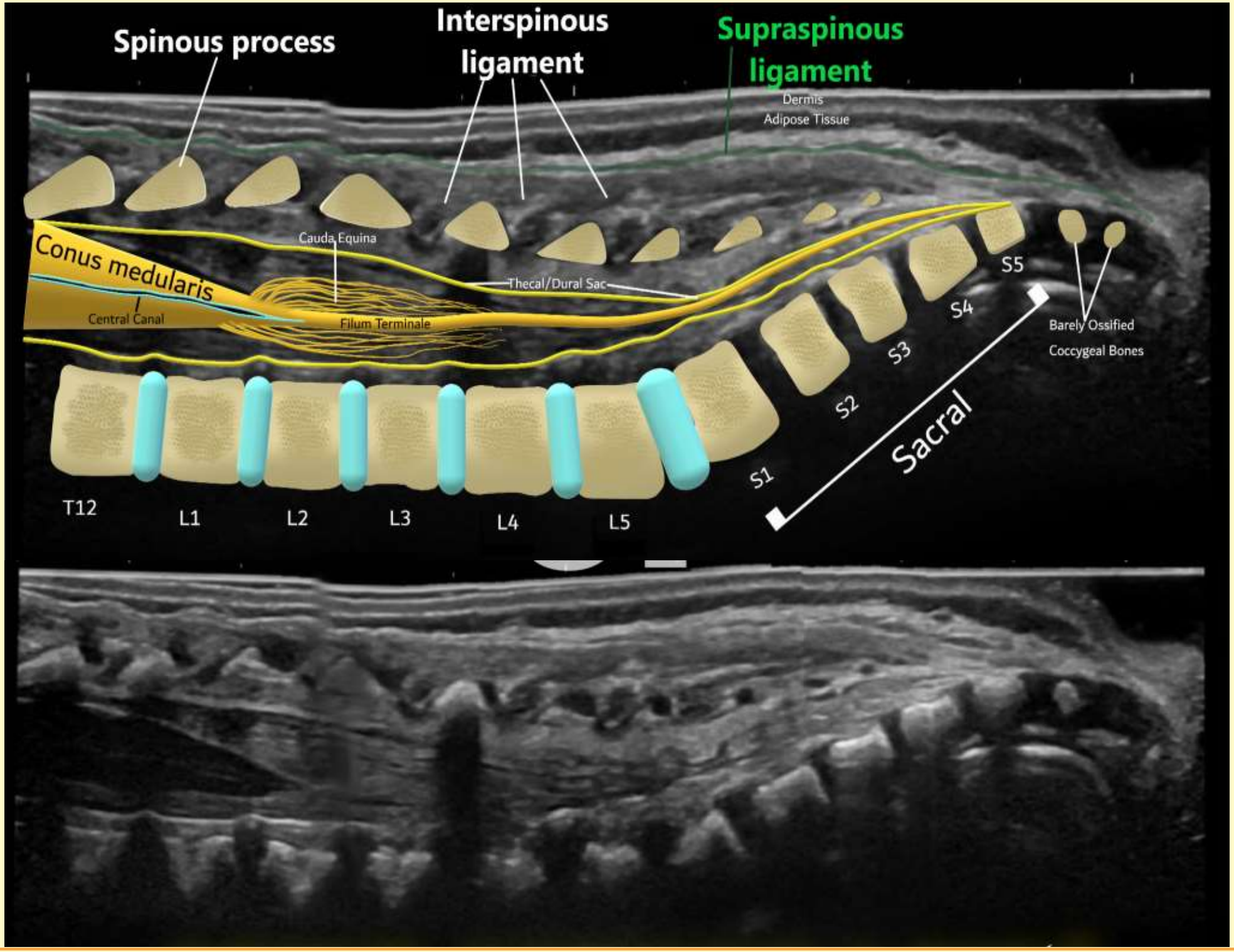
NORMAL SPINAL CANAL

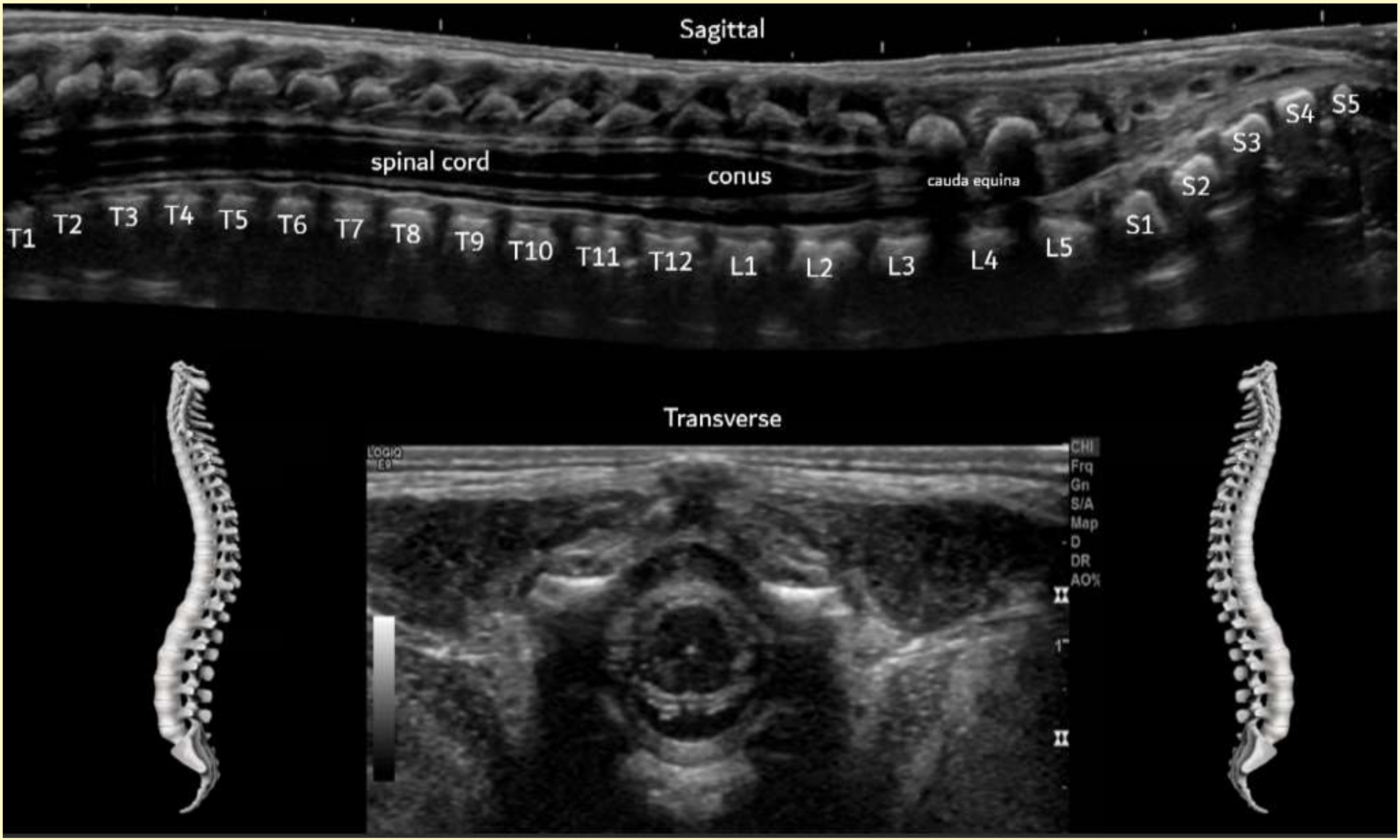
1. Posterior elements or spinous processes
2. Posterior arachnoid-dural layer bordering spinal canal
3. Subarachnoid space filled with cerebrospinal fluid
4. Posterior margin of the spinal cord
5. Spinal cord with central echo complex
6. Anterior margin of the spinal cord



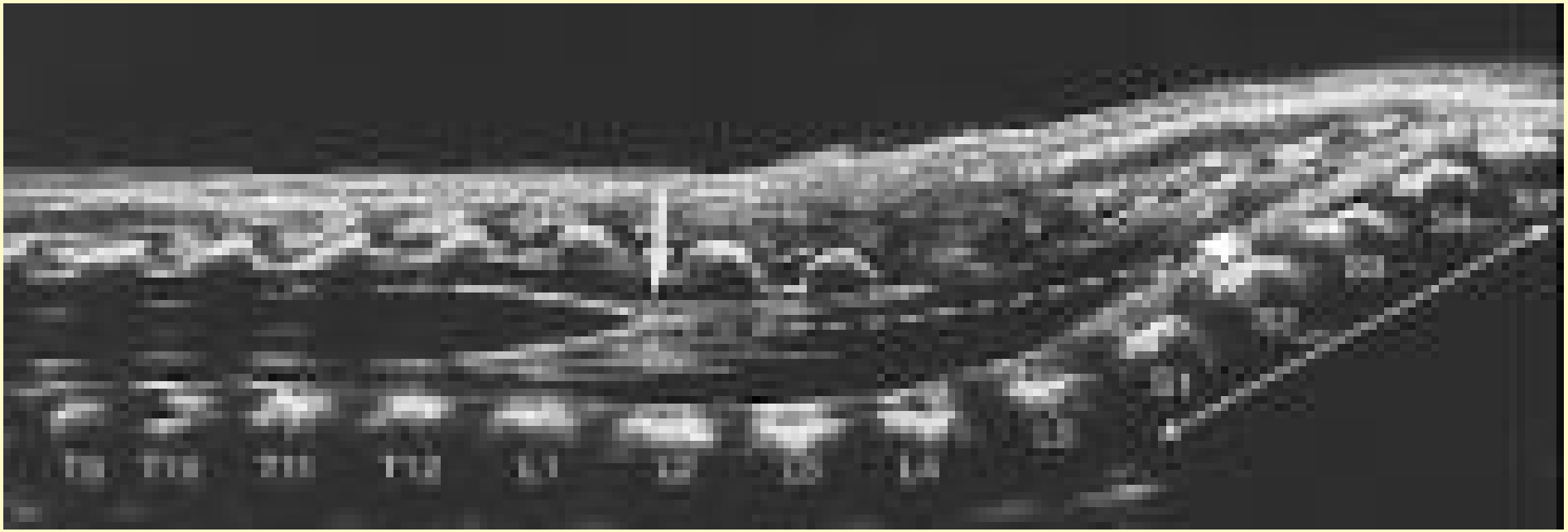
Normal conus medullaris

1. Posterior elements or spinous processes
2. Cauda medullaris
3. Filum terminale
4. Cauda equina and nerve roots


Spinous process
Interspinous ligament
Supraspinous ligament
Dermis
Adipose Tissue
Conus medularis
Central Canal
Cauda Equina
Filum Terminale
Thecal/Dural Sac
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Sacral
Barely Ossified Coccygeal Bones

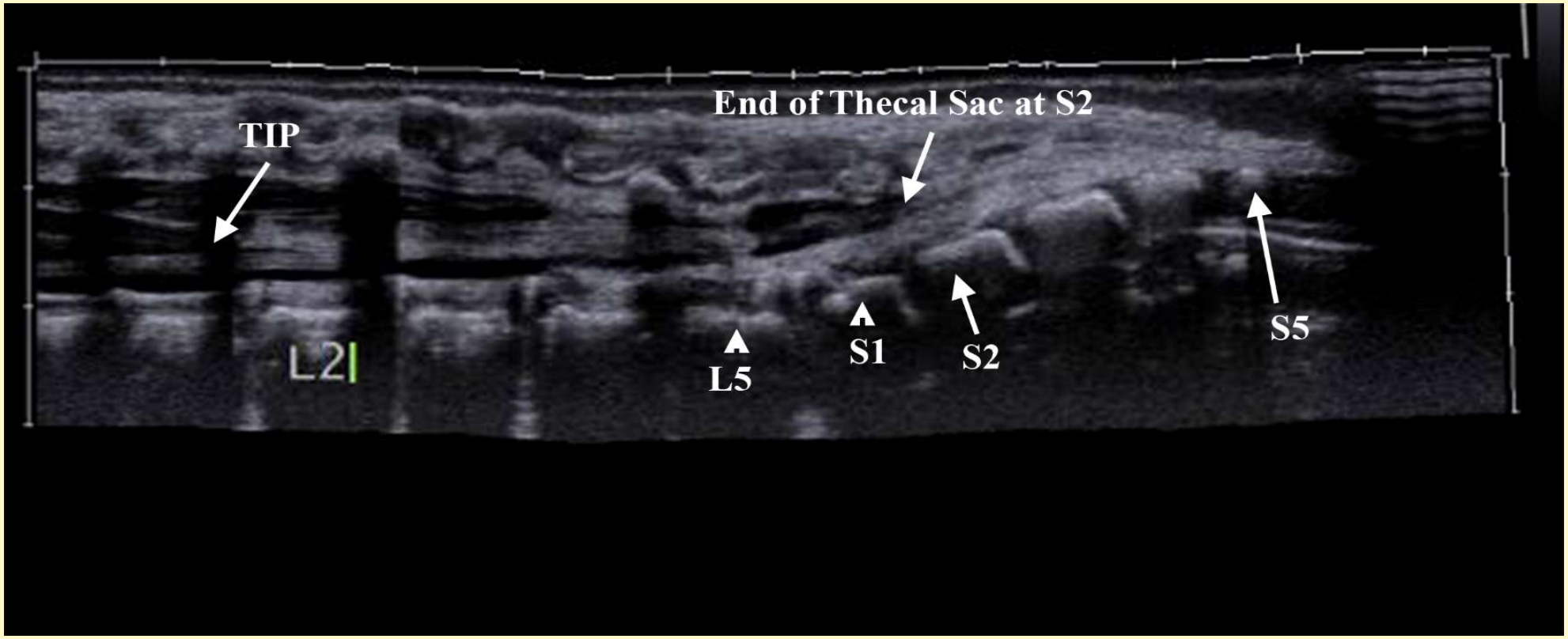

Sagittal
spinal cord
conus
cauda equina
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Transverse

Determining Vertebral Levels



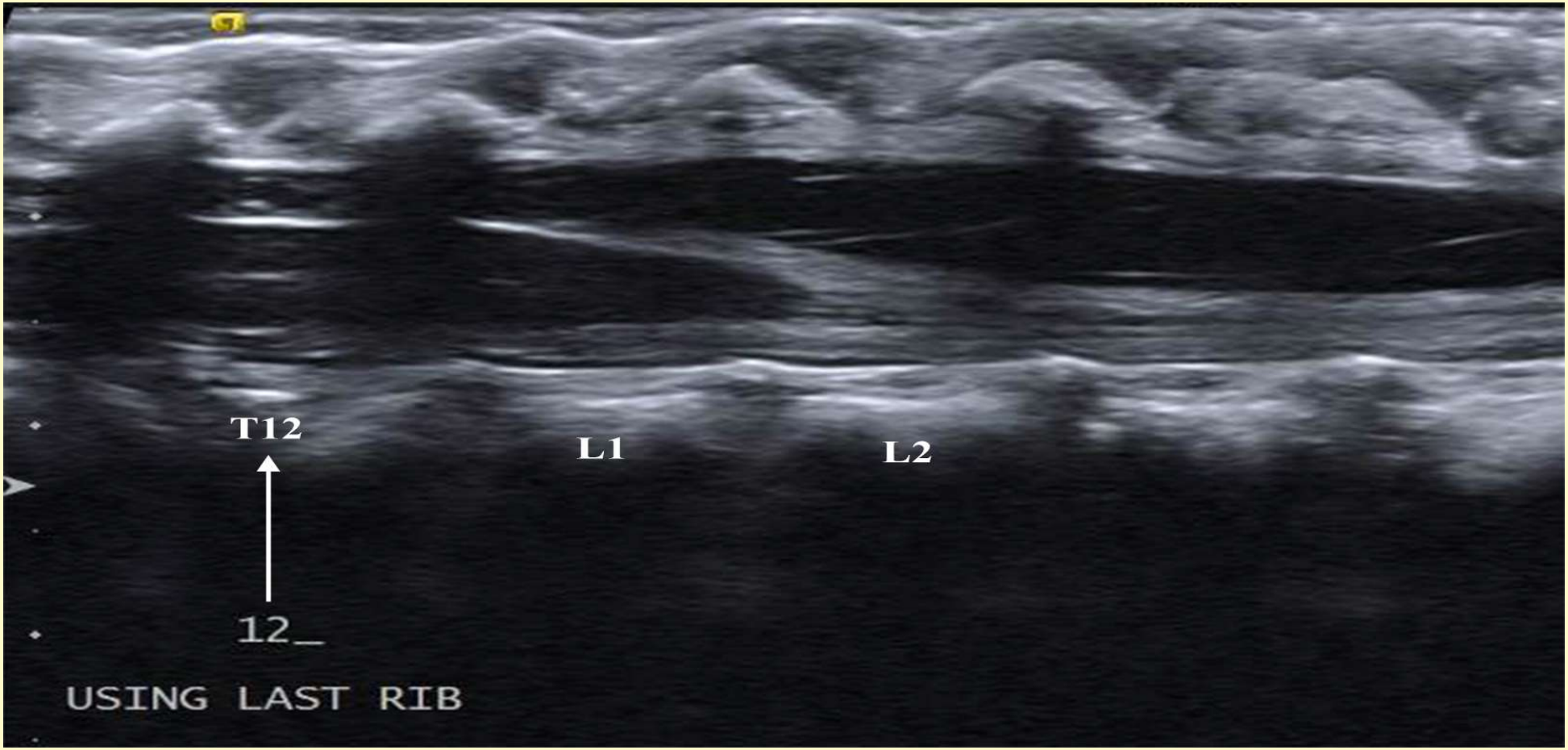
**The single most important determination is usually the level of the tip of the tapered conus medullaris.

- The normal level is in the upper lumbar canal, above the superior endplate of L3, with most cords ending at the mid L2 level



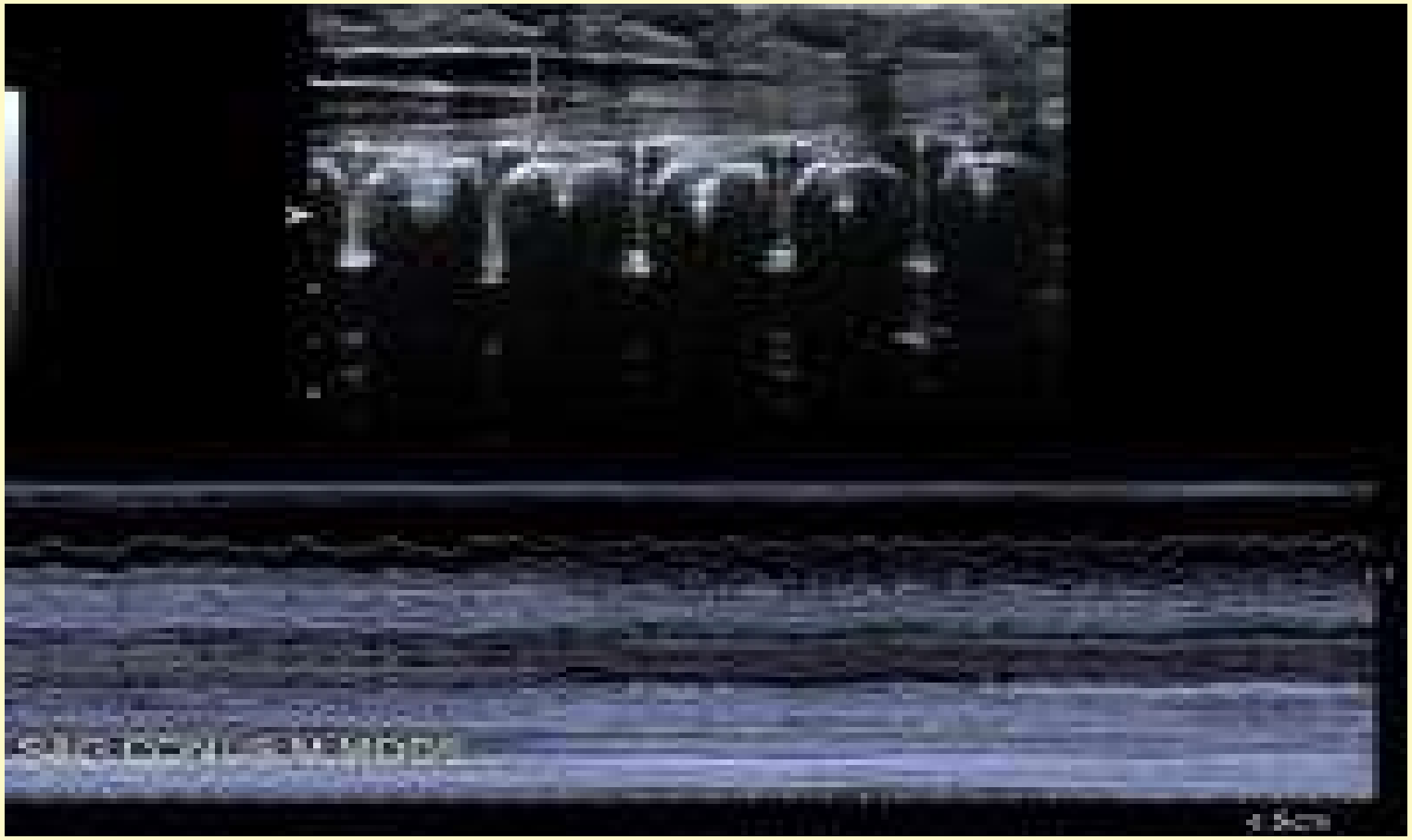
- The lumbar vertebral level achieved by counting cranial from the caudal end of the thecal sac (usually S2), from just beyond the coccyx (starting with S5, the last echogenic structure in the sacrum), or from the lumbosacral junction (L1/S5).

- Panoramic imaging is especially helpful for these methods.



Can also identify the lowest rib over each kidney from the back and follow it medially to its vertebral body.

M-mode or Cine for Cauda Equina



The nerve roots of the cauda equina should move freely, in a pulsatile fashion, and are demonstrated using a cine clip or M-mode. Normal movement is shown here in a neonate, captured at the level of the conus medularis.

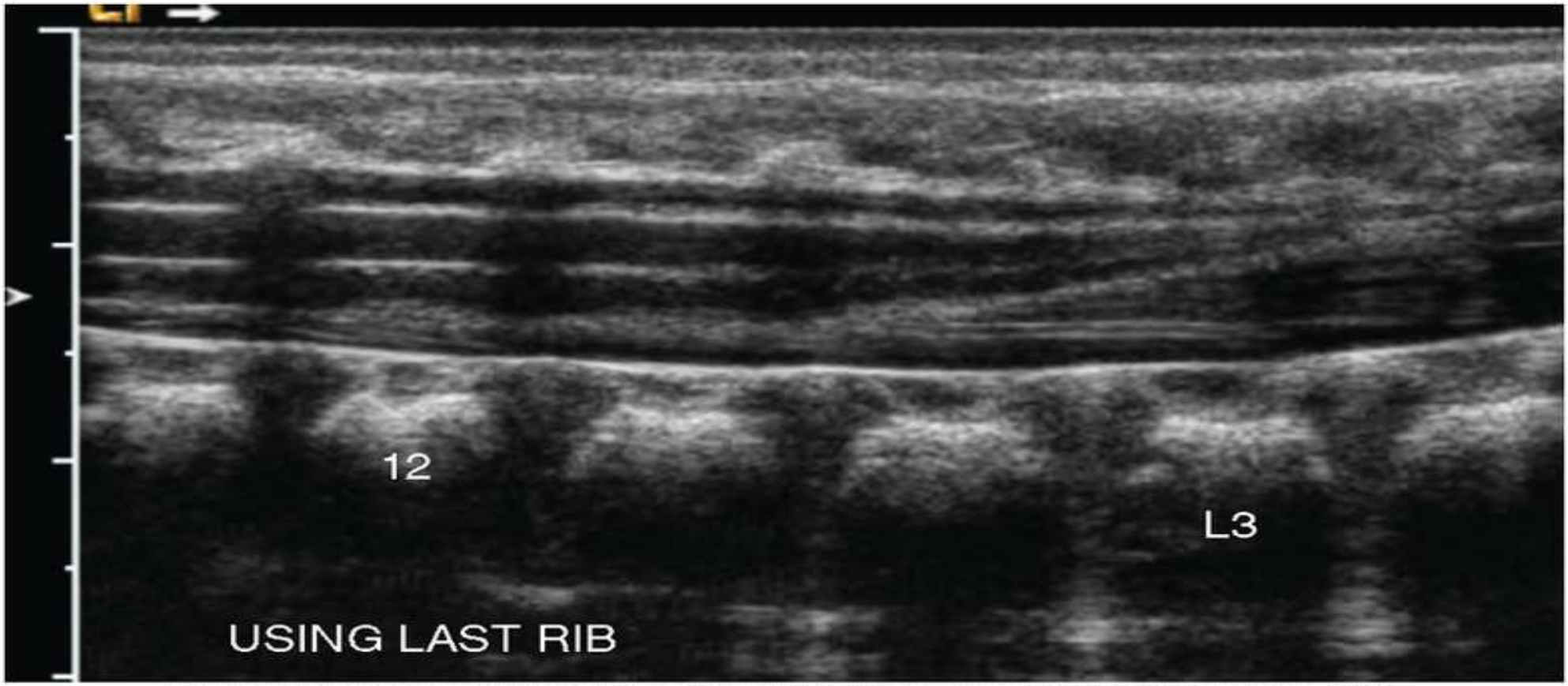
Meninges

- Same as in the brain
- Layers:
  - Dura mater
  - Arachnoid mater
  - Pia mater

Pathology

Tethered Spinal Cord

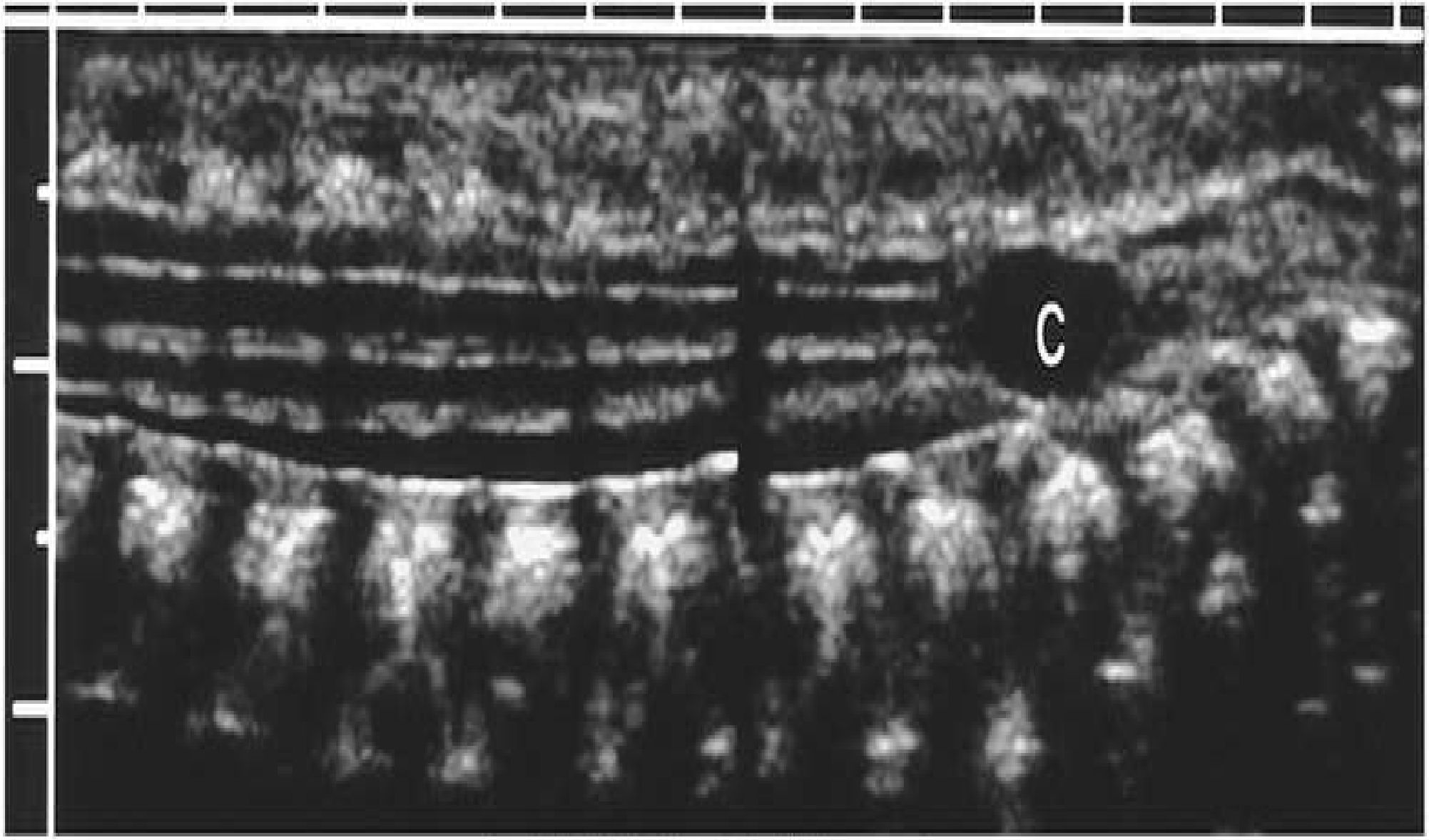
- Pathologic fixation of spinal cord in an abnormal caudal location often fixed eccentrically within canal
  - Cord suffers mechanical stretching, distortion, and ischemia with daily activities, growth, and development
- Sonographic findings:
  - A low lying conus medullaris beyond the L2 level
  - A caudal or posterior position of the spinal cord
  - Absent or dampened pulsations of the spinal cord and nerve roots
  - Thickened filum terminale (> 2mm)



(A-G, Rumack CM, et al. *Diagnostic Ultrasound*, 4th ed. Elsevier; 2011.). (Courtesy Nationwide Children's Hospital, Columbus, OH.)

Sagittal image shows the tip of the conus is extending beyond the L3 level. Poor motion of the cauda equina was noted in real-time with a cine-clip. Furthermore, the cord is seen abnormally located against the posterior portion of the spinal canal.

Tethered Spinal Cord



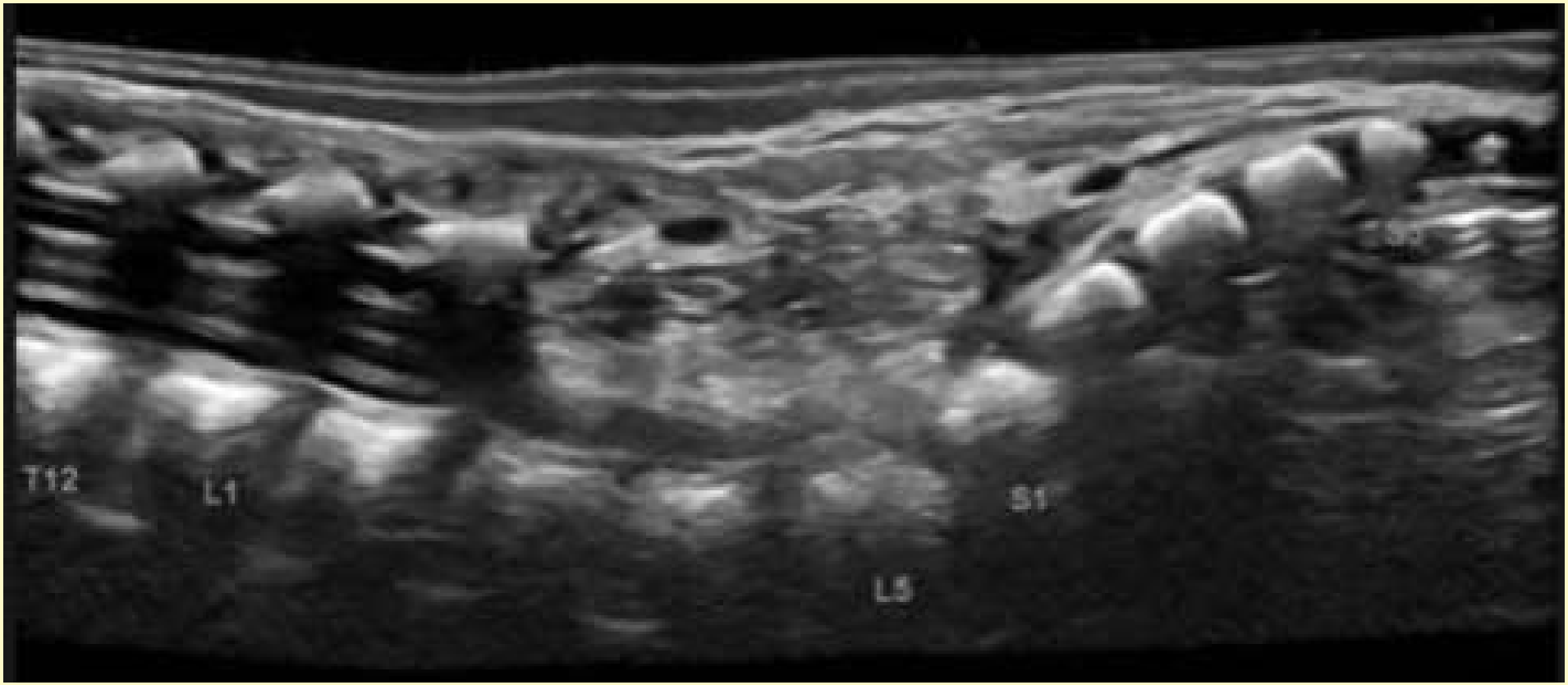
Lipoma

- Mass of filum terminale
- Usually associated with tethered cord
- Mass often has lipomatous elements and presents as a fatty lump on lower back
- Can be isolated or infiltrate the spinal cord
- Usually are echogenic and may present as a small or large mass

Lipoma (cont'd)

- Four categories
  - ✓ Intradural lipomas
  - ✓ Lipomyelocele
  - ✓ Lipomyelomeningocele
  - ✓ Fibrolipomas of filum terminale

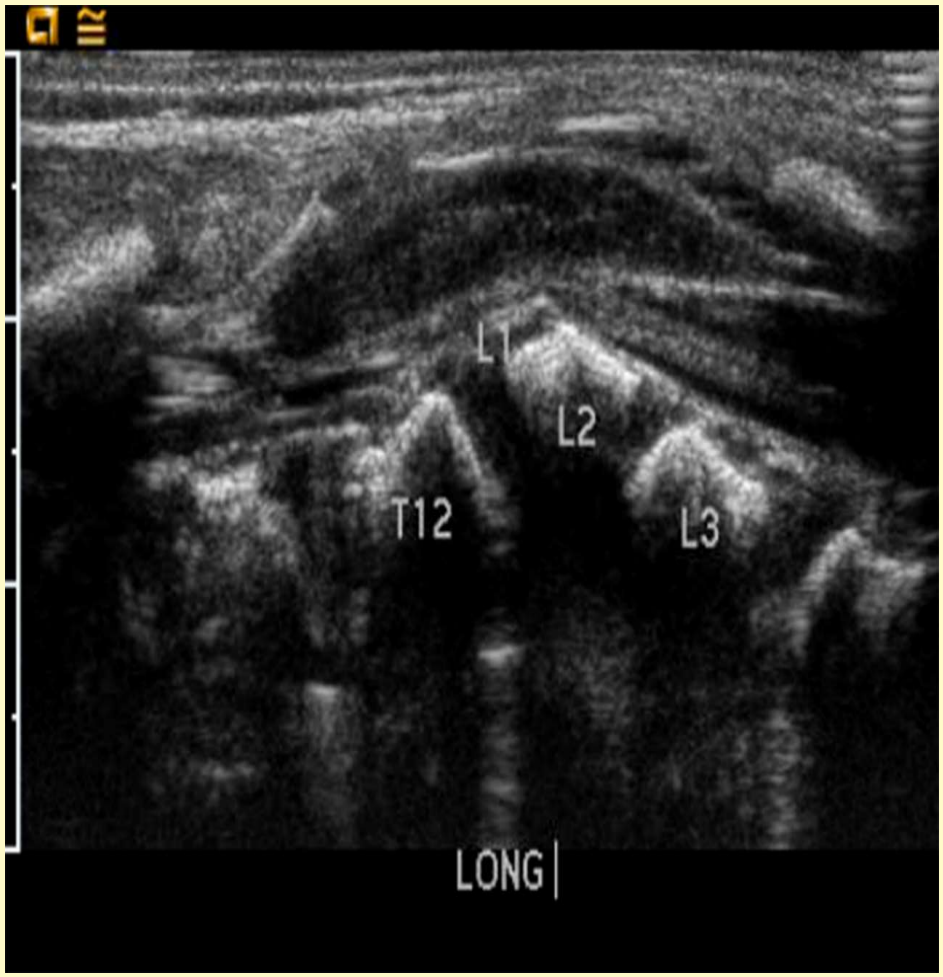
Lipoma



Hydromelia

- Dilatation of the central canal
  - Diffuse or focal
- Associated with myelomeningocele and diastemotomyelia
- May mimic or coexist with syringomelia
- Sonogrpahic findings:
  - Separation of echogenic linear structures of central canal

Panoramic image reveals acute kyphosis (flexion) of the spine at the thoracolumbar junction and a dilated central canal *(arrow)*.



Longitudinal image at the level of the thoracolumbar junction.

Diastematomyelia

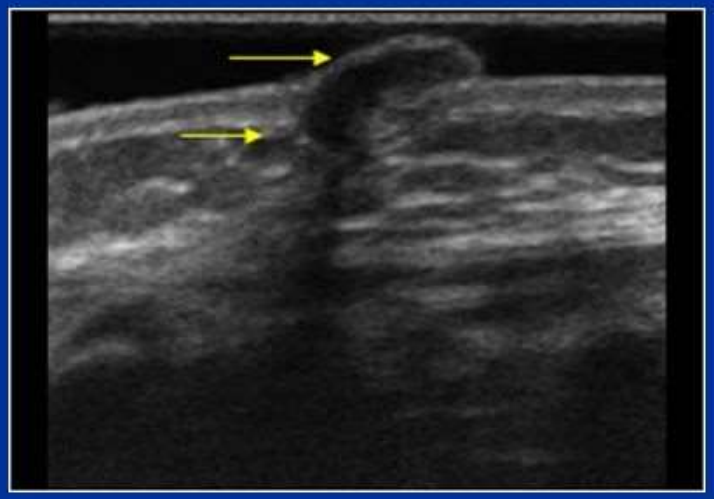
- Spinal cord is split at one or more sites by septum
- May accompany hydromelia
- Associated with meningocele or myelomeningocele
- Sonographic findings:
  - Split segments of cord- best seen on transverse views

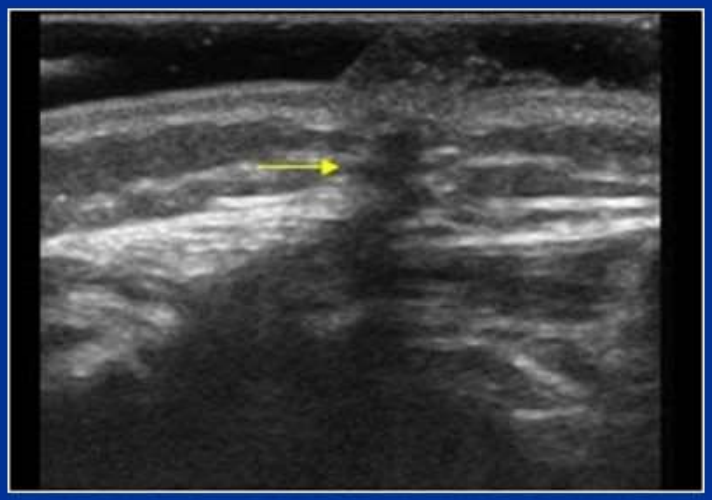
Transverse scan of the lumbar spinal canal shows left and right hemicords. Each hemicord has an eccentric central canal.

Dorsal Dermal Sinus Tract

- Thin, epithelial lined passage extending from the skin surface to the spinal canal
- Most common region is the lumbarsacral
- Risk of meningitis due to opening directly into the spinal canal
- Associated with tethered cord, intrathecal mass, or diastematomyelia
- Clinical findings:
  - Deep, midline pit
  - Leaking CSF
- Differentiate from pseudosinus tract

Dorsal Dermal Sinus





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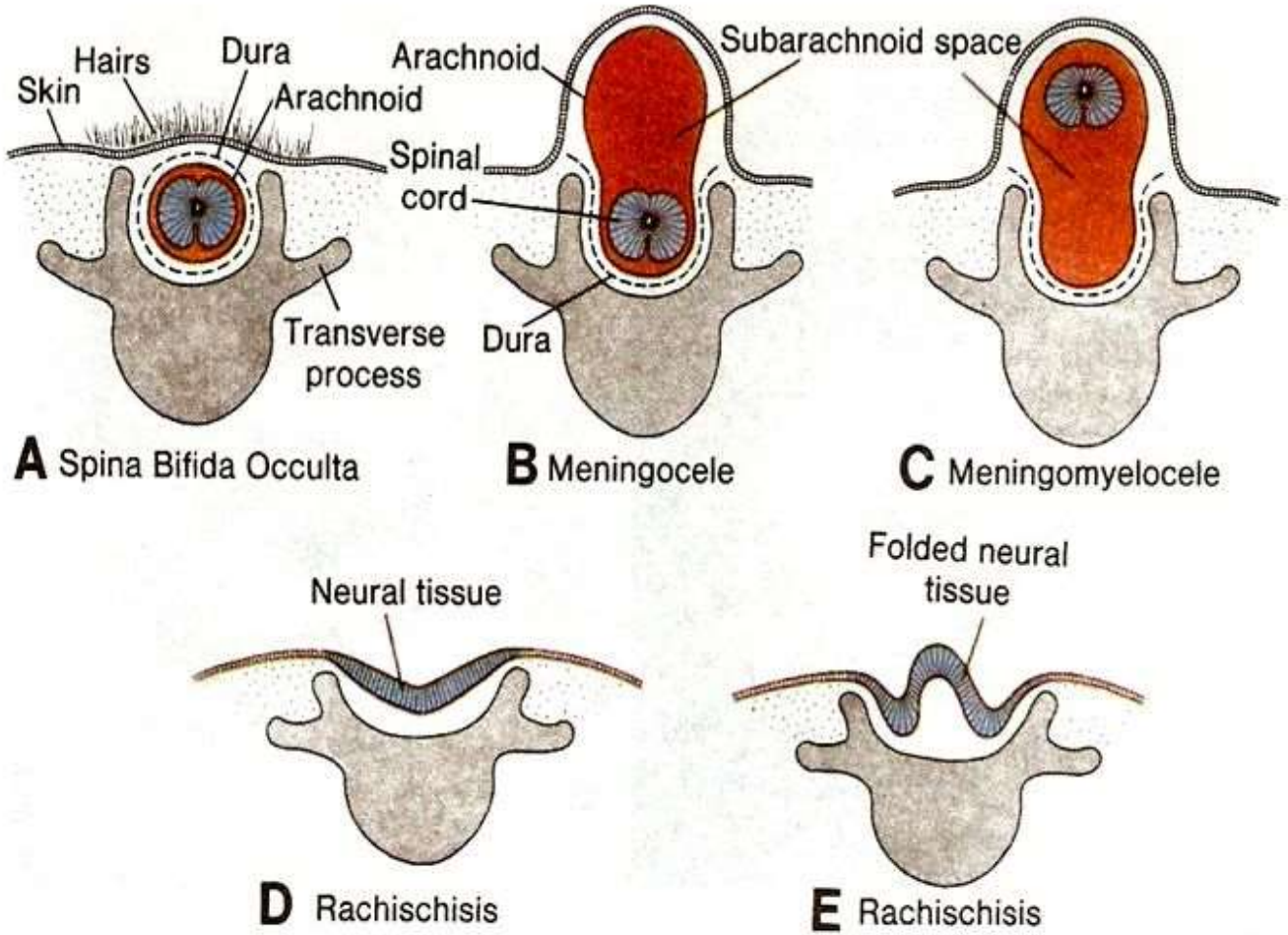
Spina Bifida

Spina Bifida



Spina Bifida Occulta vs. Aperta

- **Occulta**
  - Neural tube defect where the area is still covered by skin and underlying tissue and muscle
- **Aperta**
  - Neural tube defect where the skin, underlying tissue, and muscle are missing, and the dura can protrude outside the body
  - Aka. Open spinal dysraphism

Spina Bifida Occulta

- Mildest form of spina bifida
- Most common
- Aka. closed spinal dysraphism

Types of Spina Bifida Aperta

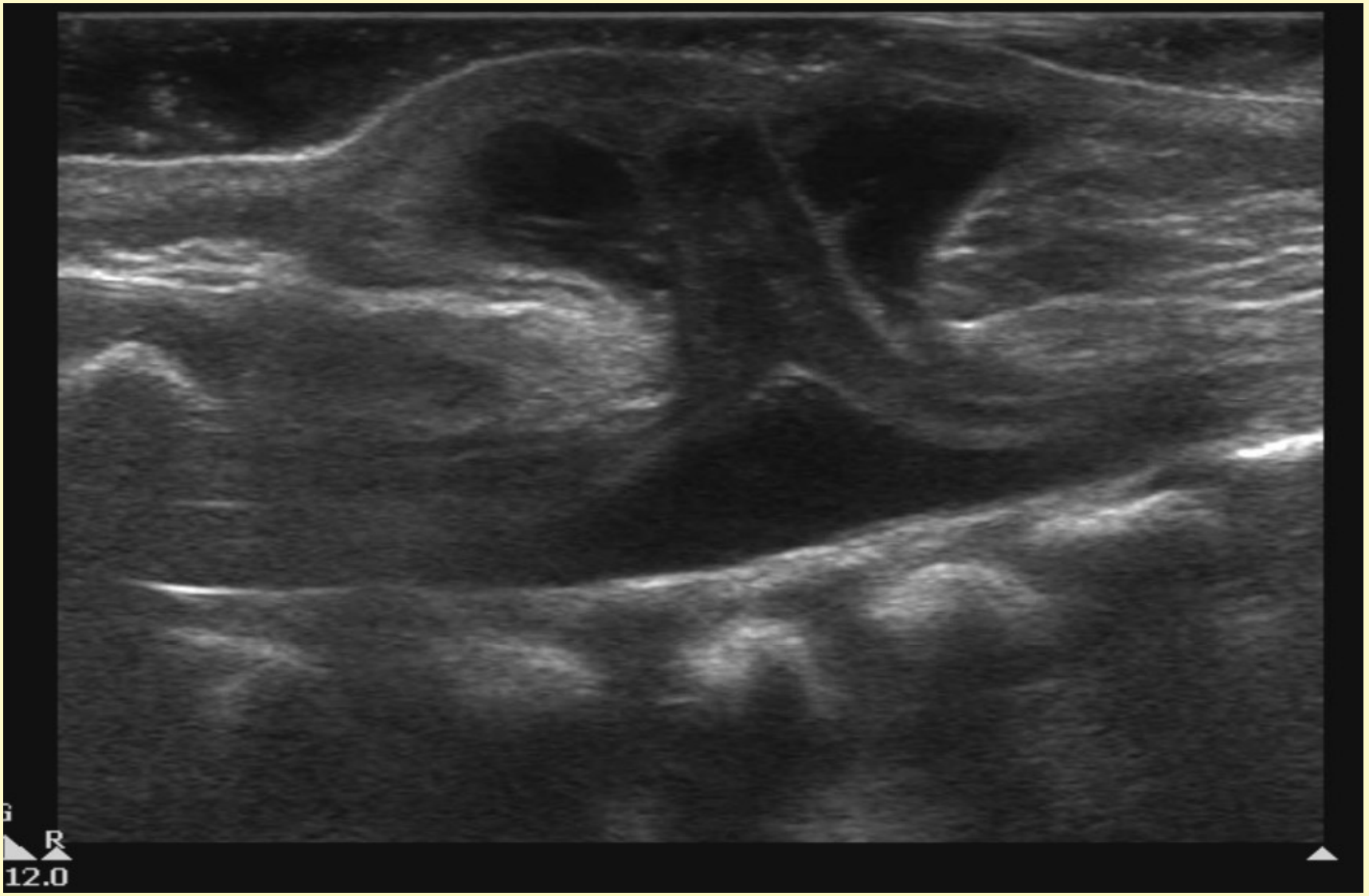
Meningocele

- Least common form of spina bifida
  - Aka. spina bifida cystica
- Sac contains only cerebrospinal fluid

Myelomeningocele

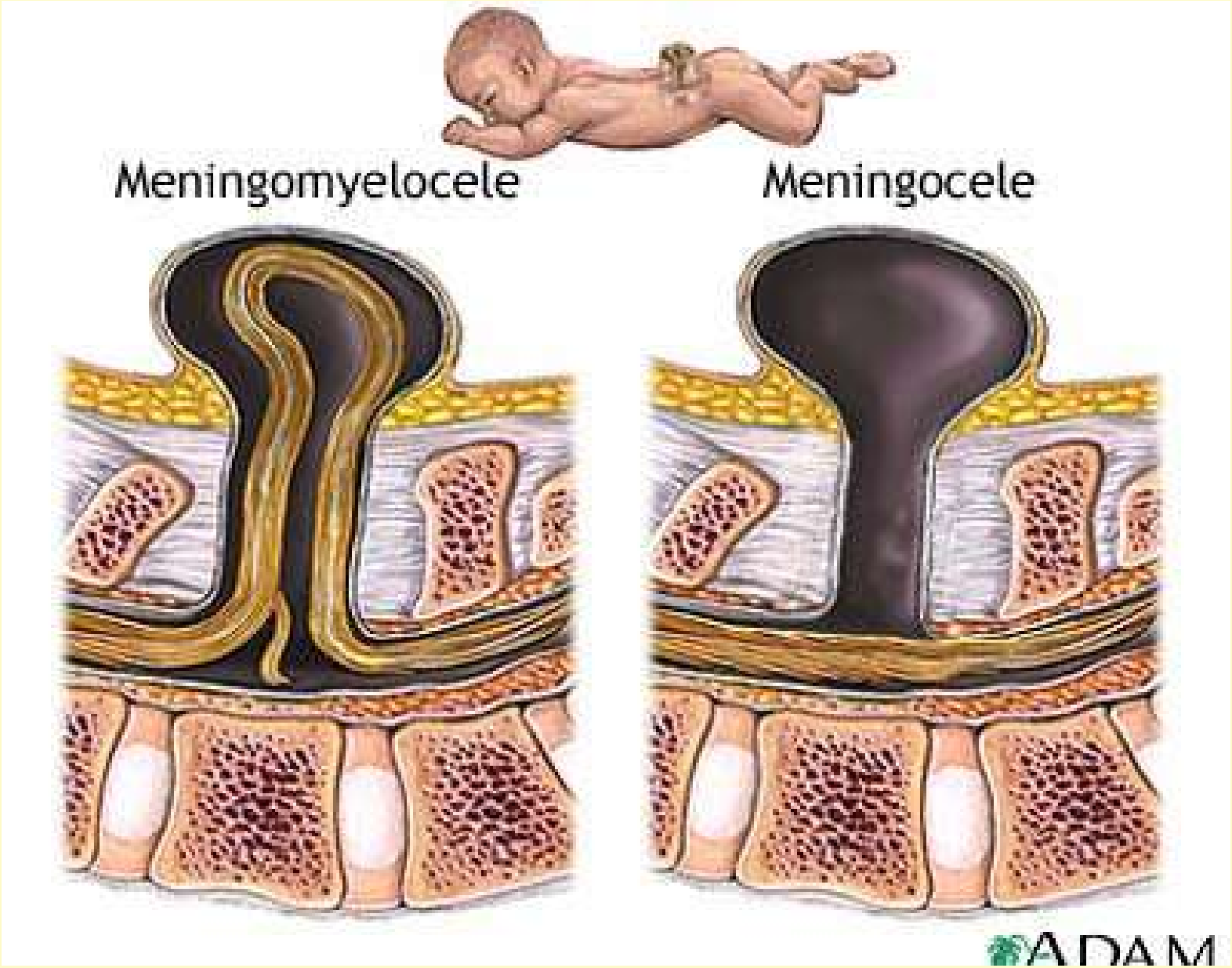
- *Most common open spinal defect (98%)
- Spina bifida with a sac containing herniation of both meninges and nerves

Myelomeningocele



Myeloschisis

- Aka. rachischisis
- Most severe form of spina bifida
- Defect is uncovered, exposing the nerves


Meningomyelocele
Meningocele

Other Indications and Associations

- Midline cutaneous abnormalities over lower back
  - Most common reason for sonography
- Midline dimples over lower back occur in approximately 2% to 4.3% of newborns
  - Most are low sacral or coccygeal without an associated tethered cord

Other Indications and Associations (cont'd)

- Neonatal coccyx usually is of very low echogenicity
  - Should not be mistaken for a cyst or fluid collection
- During first month of gestation, neural tube is closing while neural and epithelial tissues are differentiating from overlying ectoderm
    - These events might explain coincidence of midline cutaneous and spinal defects

Other Indications and Associations (cont'd)

- Search for an occult tethered cord if the following are found on the back:
  - Midline hair patches
  - Fatty lumps
  - Skin tags
  - Lumbar dimples
  - Hemangiomas
    - Have a high association with tethered cord
- Tethered cord has an association with neonates with imperforate anus

Other Indications and Associations (cont'd)

- Sonography can be useful to evaluate spinal cord injury, such as birth trauma or failed lumbar puncture
- Can evaluate for retethering postoperatively or to visualize the spinal fluid for characteristics of blood products in patients with intracranial hemorrhage

REVIEW

https://youtu.be/zjwG_Iv0K_E?si=xdJoxFy70baQD85D

https://youtu.be/JCQ9W9Ysrj0