THE BASICS OF ULTRASOUND PHYSICS
Ultrasound Guidance for Regional Anesthesia

Allows the operator

– to see neural structures (as well as vascular, lung bowel)
– guide the needle under real-time visualization
– navigate away from sensitive anatomy
– monitor the spread of local anesthetic
Ultrasound waves

- Infrasound  0-20 Hz
- Audible sound  20 Hz to 20,000 Hz
- Ultrasound  >20,000 Hz (or 20 KHz)
- Medical ultrasound  2.5 MHz to 15 MHz
Anatomy of a wave

Wavelength, $\lambda$

Amplitude, dB

Compression

Rarefaction

Velocity, m/s

direction
Formation of ultrasound image

Piezoelectric crystals

Object
Formation of ultrasound image
(continued)
Appearance of anatomic structures

- **Hyper-echoic:**
  - White structures/areas on the screen
  - Ultrasound waves are reflected
  - Tendons, fascia, bones...

- **Hypo-echoic:**
  - Dark structures/areas on the screen
  - Ultrasound waves are not reflected
  - Vessels, cysts...
Echogenicity: Fluid
Echogenicity: Fat and Muscle
Appearance of anatomic structures (continued)

- Nerves appear differently at different locations
Structures with similar appearance on ultrasound

- Nerves
- Tendons
- Ligaments

Sites B et.al. The Internet Journal of Anesthesiology. 2005(10) 1.
KEY CONCEPT: Penetration and Resolution

Penetration
- Superficial
- Deep

Frequency
- High
- Low

Resolution
- High
- Low
Transducers and Image Resolution

5-13 MHz
Good spatial resolution; limited penetration depth

4-11 MHz
Greater penetration depth; decreased resolution
Infraclavicular PNB Appearance
Infraclavicular PNB Appearance
Gain

- Allows the operator to artificially change the intensity of the returning beam
NEEDLE APPROACH
Needle Visualization

• Oblique Plane

WHERE’S THE TIP???
Needle Visualization
Needle Visualization
Transducer Movement

Sliding

Rotating

Tilting
Ultrasound Guided Regional Anesthesia

Neuraxial Anesthesia

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Ultrasound Guided Neuraxial Anesthesia
Ultrasound for Neuraxial Anesthesia

• Permits passage of US waves through an interlaminar window providing imaging of the vertebral canal revealing a path into which a needle can be passed

• Also aids in identifying:
  – Intervertebral level
  – An estimation of the depth to epidural and to intrathecal spaces
  – The location of important landmarks (midline and interlaminar spaces)

• When should it be used?
  – Obesity/poor surface anatomy
  – S/p spinal surgery
  – Distorted spinal anatomy (elderly pts or scoliosis)
  – Pregnancy and preeclamptic patients with presacral edema
Anatomy

- The “interlaminar space” and “interspinous spaces” refer to the gaps between adjacent laminae and spinous processes.

- Lumbar Spine: laminae do not overlap (as they do in T-spine) and there is a distinct interlaminar space between adjacent vertebrae.

- The posterior epidural space has a triangular cross-section, typically 7 mm wide in the midline in an anteroposterior dimension.

- Conus medullaris is located at L1 vertebral body in most adults (varies from T12 – L3).
Sonoanatomy of the Spine

• A curved-array, low frequency probe (2 – 5 MHz) allows for a wider field of view and deeper penetration

• Initial depth setting of 7 – 8 cm is appropriate for most patients; adjust depth, focus, and gain as needed

• 3 basic orientations of the ultrasound probe and beam:
  - 1) Paramedian sagittal (sagittal plane lateral to midline)
  - 2) Paramedian sagittal oblique
  - 3) Transverse
Sonoanatomy of the Spine

- Bony structures appear as white, hyperechoic linear structures with a dense acoustic shadow (black)

- Connective tissue structures (ligaments & fascial membranes) are also hyperechoic, however have a lesser acoustic impedance thereby allowing limited visualization of deeper structures

- Fat and fluid appear hypoechoic (dark) and have a very low acoustic impedance
Ultrasonographic Views of the Spine

5 Basic Views

1. PS Transverse Process View
2. PS Articular Process View
3. PS Oblique View
4. Transverse Spinous Process View
5. Transverse Interlaminar View

Anatomic Planes and US Probe Orientations
Longitudinal Views

http://pie.med.utoronto.ca/OBAesthesia/OBAesthesia_content/OBA_spinalUltrasound_module.html
#1 Parasagittal Transverse Process View

- Place probe in a PS orientation 3 – 4 cm from the midline just above the upper border of the sacrum

- TPs of successive lumbar vertebrae are visualized – “Trident Sign”

- Psoas major m. is visible btw acoustic shadows and deep to the TPs
#2 Parasagittal Articular Process View

- From TP view, slide the probe medially until a continuous hyperechoic line of “humps” is seen.

- Each hump represents the facet joint between a superior and inferior articular process.
• From previous view, tilt the probe toward the midline

• Sloping hyperechoic laminae form a “sawtooth”-like pattern

• Intervening gaps represent the paramedian interlaminar spaces*

*Window to anterior and posterior complexes
Interlaminar Spaces of the Parasagittal Oblique View

- From superficial to deep:
  - Posterior Complex
    - Ligamentum flavum
    - Epidural space
    - Posterior dura mater
    - Intrathecal space
  - Anterior Complex
    - Anterior dura
    - Post longitudinal ligament
    - Posterior vertebral body
Accurate identification of intervertebral spaces

- Slide the probe caudad while maintaining a PS oblique orientation, until the horizontal hyperechoic line of the sacrum comes into view

- Center L5–S1 intervertebral space on the screen

- This location corresponds with the midpoint of the probe’s long side

- Same approach to count up
Surface Marking for Needle Insertion
Transverse Views

Transverse Spinous Process View

Transverse Interlaminar View

http://pie.med.utoronto.ca/OBAAnesthesia/OBAAnesthesia_content/OBA_spinalUltrasound_module.html
#4 Transverse Spinous Process View

- Rotate probe 90 deg and centered on neuraxial midline

- The tip of the SP is visualized as a superficial hyperechoic line with acoustic shadowing beneath

- Hyperechoic lamina is visible on either side of the spinous process, but all other structures of interest are obscured by bony acoustic shadowing
#5 Transverse Interlaminar View

- Slide the probe cephalad/caudad from the spinous processes.

- Midline is indicated by the dark vertical stripe of interspinous ligament.

- Estimate the required needle insertion depth by measuring depth from skin to posterior complex.
“Flying Bat” sign

http://pie.med.utoronto.ca/OBAnesthesia/OBAnesthesia_content/OBA_spinalUltrasound_module.html
Atypical Sonogram

http://pie.med.utoronto.ca/OBAesthesia/OBAesthesia_content/OBA_spinalUltrasound_module.html
Conclusions

• Ultrasound: a promising technical advance in spinal and epidural techniques
• Bedside ultrasound can be extremely useful to facilitate spinal and epidural anesthesia placement by providing the following information:
  – the exact interspace at which the puncture should be performed, which is especially important in spinals,
  – the best interspace,
  – the ideal insertion point,
  – the angle of the puncture,
  – the distance from the skin to the epidural space, and
  – anatomical abnormalities, such as scoliosis
Conclusions

• Providing a superior teaching tool for spinals and epidurals, as it facilitates the learning curve, and may increase safety during the learning curve,
  – shortening the duration of procedures,
  – increasing the comfort of procedures,
  – decreasing the number of attempts and the associated trauma,
  – possibly decreasing the number of accidental dural punctures,
  – forecasting difficult epidurals (similar to difficult intubations),
  – transforming difficult epidurals into easy epidurals, and
  – helping in the selection of the best equipment for the spinal/epidural.