Ultrasound Guidance in Anesthesia Practice

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Objectives
- Describe the basic principles of ultrasound
- Explore the various applications of ultrasound in anesthesia practice
- Discuss the benefits of using ultrasound to improve patient safety and satisfaction

Why Use Ultrasound???
- Increased success of performing procedures
- Decreased risk of inadvertent arterial or nerve puncture
- Reduction of number of attempts to be successful for procedures
- Decreased length of procedure time
- Ability to assess anatomy

And because we don’t have....

Safety of Ultrasound
- Ultrasound produces some heat with use which can transfer into tissues.
- In over three decades of medical ultrasound use, there has never been a report of injury to patients or operators from medical ultrasound equipment. (American Institute of Ultrasound in Medicine, 1994)
History of Ultrasound

- Ultrasound = Sound that cannot be heard (cyclic sound with a frequency greater than the upper limit of human hearing)
- Discovered by an Italian priest in the 1700s - Lazzaro Spallanzani
- Experimented with bats

Physics of Ultrasound

- Sound travels in waves
- Speed of sound = frequency X wavelength
- Ultrasound is high frequency sound
  - Over 20,000 cycles/second (20kHz)
  - Typical ultrasound frequency is 2 – 15 MHz

Creating ultrasound

- In 1880 Jacques & Pierre Curie, French physicists, described the transformation of electrical energy into mechanical energy and vice versa
  - “Piezoelectric effect”

Piezoelectric Effect

- Piezoelectric crystals (PZT) are located in the transducer probe head.
- When electric energy is applied to the crystals, they vibrate, emitting ultrasound waves
- The sound goes out and is reflected back to the transducer and to the PZT crystals
- The energy is then measured by the machine, and the difference from out/in waves calculated
Ultrasound Equipment

Four basic components of an ultrasound unit:

- Display
- Transmitter
- Transducer probe
- Receiver

Anatomy of a transducer probe

Image from www.genesis.net

Speed of sound in different tissues

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Speed of sound (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>300-1,200</td>
</tr>
<tr>
<td>Fat</td>
<td>1,450</td>
</tr>
<tr>
<td>&quot;Soft&quot; tissue</td>
<td>1,540</td>
</tr>
<tr>
<td>Bone</td>
<td>2,000-4,000</td>
</tr>
<tr>
<td>Blood</td>
<td>1,570</td>
</tr>
</tbody>
</table>

Transmission and reflection of US (echogenicity)

The greater the difference between tissues, the more reflection will occur back. (larger contrast)

Image Generation

A math equation converts the signals to a picture

Examples of transducers

Linear:
- OB, urology
- Soft tissue, vascular, thyroid, breast, etc.

Curvilinear:
- Abdomen, Early OB, kidney, etc.
As a siren approaches, you hear one pitch (frequency), as it passes, it sounds lower.

**Doppler Effect**

- **Negative Shift**
- **Positive Shift**

- **Cephalad**
- **Caudal**

**Effect of Gain Adjustment**

**Effect of Probe Angle**

- Orient yourself longitudinally using doppler and the “imaginary transducer”
- When you apply the doppler “box” to the image on the screen, the top of the box leans toward the imaginary transducer
Longitudinal orientation, con’t.

- In the example above, the top of the box leans towards the left, which means that the imaginary transducer is also on the left but looking right, so the blood in the top vessel is going AWAY from the probe and blood in the bottom vessel is going TOWARDS the probe.
- This technique allows you to always know artery from vein.

Ultrasound Guidance: Dynamic vs. Static

Dynamic
- Consists of ultrasonic localization, and image-guided cannulation
- More precise and “real time”
- Difficult to keep sterility of transducer site
- More hand to screen coordination

Static
- Consists of ultrasonic localization and marking of landmarks only
- Cannulation is not image guided, but is separate
- Time delay between marking and cannulation
- Easy to keep sterility of transducer and site
- Less technically demanding

Getting Started:

- The two most important elements of using ultrasound:

Establish a Routine

- Gather equipment and supplies
- Prepare patient - position comfortably
- Prepare provider - position comfortably and place machine in your line of vision
- Know what the anatomy should be
- Know what probe you need
- Practice, practice, practice!!

Tips: Proper positioning

- Put the US machine in your line of sight (the needle should point toward it during cannulation)

Preparing the probe

- Probe must be placed in sterile sleeve
- Note large amount of ultrasound gel on probe surface
- Now ready to use
Transverse orientation - first rule

When applied to the patient, the notch on the probe must be on the same side as the dot on the screen, otherwise you will be looking at a mirror image.

Transverse orientation - “finger wiggle”

Finger on one side of the probe

Acoustic shadow of finger on same side of image

Orientation - “mock poke”

Tips: Make sure you keep the needle tip in view by angling or moving the transducer

In this example, the needle is in the right place, but you don’t know that by looking at views A, B, C, or D.

US Guidance for Central Vascular Access

- The 2001 Agency for Healthcare Research and Quality (AHRQ) Evidence Report listed ultrasound assistance of central cannula placement as one of the “Top 11 highly proven” patient safety practices that are not routinely used in patient care.

- NICE (Britain) Guidelines:
  - US is the preferred method of IJ insertion in non-emergent situations
  - US should be considered in emergent situations
  - Proper training is required

- Meta-analysis in BMJ 2003:
  - 2-D US associated with:
    - 86% risk reduction: failure
    - 57% RR: complications (arterial stick, PTX, etc)
    - 41% RR: repeated sticks


Keenan (J Crit Care. 2002; Jun 17(2): 126-37)

- Systematic review of 18 RCT of ultrasound-guided CVP placement vs. using landmarks alone
- Significant reduction in procedure failure rate, number of attempts and arterial puncture rate
- Increased rate of successful placement with ultrasound
- Inexperienced clinicians placing IJV catheters may benefit the most

ASA Task Force on Central Venous Access- March 2012

- Practice guidelines recommends use of both static- and real-time ultrasound imaging for internal jugular placement and subclavian/femoral when possible
  - Vein identification (static)
  - Vessel localization and venipuncture (real time)
  - Confirming venous access (needle, catheter in vessel)

Anesthesiology 2012; 116:539-73.

Figure 2. Presentation of variations in the position of the internal jugular vein in relation to the common carotid artery (CA). The figure shows the expected position of the internal jugular vein, subclavian and femoral veins. The figures on the left side of the figure show the relationships of the subclavian and common carotid arteries and the number of patients in the relevant studies.

Maecken, T Crit Care Med. 2007; Vol. 35 No.5 (Supp)

Insertion Method

- Transverse orientation- IJ
- Longitudinal orientation- IJ

Anatomical Variations

Carotid Artery and Internal Jugular Vein

Longitudinal IJ
**Check compressibility**

Vein should be free of clot and freely compressible when pressure is applied with the probe.

**Check vein for patency**

**Basic Insertion Method**

Vein cannulation under dynamic guidance.

- For insertion of the needle, using transverse view is preferred.
- Can see acoustic shadow of needle.

**Ultrasound confirms vein cannulation**

**Subclavian Lines**

- Subclavian is more difficult to visualize with ultrasound; static guidance is possible.
- Must manipulate/angle the probe to “see” under the clavicle.
- Cumbersome and technically difficult to cannulate vessel under dynamic guidance.
- Why struggle? go for the IJ or axillary, unless subclavian line is essential.

**Axillary Vein**

- The mid portion of the subclavian vein lies under the clavicle.
- The lateral SCV and axillary vein travel inferiorly and, thus, become “exposed.”
- This exposure facilitates insonation and cannulation under direct guidance.
Axillary Vein

The diameter of the vessel becomes very small laterally, and the depth increases substantially.


Study of 101 emergency department patients with history of difficult intravenous access.

Patients had two unsuccessful attempts at establishing a peripheral intravenous line.

Ultrasound guidance was used to cannulate the deep brachial or basilic vein with a 2 inch 18-20 gu catheter.

91% had successful catheter placement with US, 73% on first attempt.

Antecubital vein

½ cm Depth

Deep brachial vein

Longitudinal view basilic vein

Basilic Vein
Catheter in Vein

Catheter appears bright in vessel.

Arterial Cannulation

- Arteries will appear pulsatile
- US allows the artery to be checked for stenosis
- Normally are non-compressible
  - Patients who are in a low-flow state can have compressible arteries
  - Appear thicker-walled than veins

Radial artery

Translaryngeal Ultrasound

Translaryngeal Ultrasound

Vascular structures can be marked
Tracheal rings numbered
Location and size of thyroid gland confirmed
All vascular and soft tissue anatomical abnormalities identified prior to attempted intubation

Airway Assessment

Thyroid Tissue
Arytenoids
Tracheal Ring
Caudal artery
Mapping: “diving trachea”

Vocal Cords

Mapping the Neck: Depth

Ascertaining endotracheal tube position

- Can do translaryngeal U/S to look for proximal ETT malposition
  - Esophageal
  - Too shallow/deep
  - Unilateral pleural sliding may indicate mainstem intubation; b/l pleural sliding normal

- Combination of both may eliminate need for x-ray

Transverse view showing ETT
Longitudinal view showing ETT

Cephalad

Lung Assessment - Pleura

- Easily accessible to U/S study
- Can rule out pneumothorax/effusions

Note tissue appears to “shimmer”

Normal Lung

Pneumothorax

“Seashore” sign is normal. Would see “barcode” in PTX (looks like the top part of the image all the way down to the bottom of the picture)

US Guidance for Regional Anesthesia

- Cochrane Review (2009) found that US guidance for regional anesthesia resulted in:
  - Decreased time to perform blocks
  - Faster onset of effective block
  - Reduced amounts of local required
  - Reduction in tissue trauma

US Guided Regional Anesthesia

- Study by Mariano (2009) showed ultrasound guidance for infraclavicular brachial plexus perineural catheters is quicker and more successful than electrical stimulation.

- Recent case report by Schober (9/2009) described successful use of ultrasound-guided regional anesthesia in a patient with progressive fibrodysplasia ossificans (stone-man’s disease) for an ankle block.
**Identifying Nerves with U/S**

- Knowledge of relevant anatomy is most important
- Nerves are not always easy to identify
- Identify associated anatomical structures such as arteries, bony landmarks
- “Traceback” method: obtain an obvious anatomical landmark not too far removed from one point along the target nerve’s path

**U/S Appearance of Nerves**

- Nerve tissue is denser than muscle and appears brighter (hyperechoic)
- Nerves can appear hollow on ultrasound (like vessels without flow)
- Neurovascular bundles in transverse orientation can appear grape-like
- Doppler imaging can help to differentiate nerves from vessels

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**Brachial plexus**

Local “spread” appears like a black area around the nerve bundle

**Interscalene block**

**Appearance of air bubbles- ISB**
Interscalene Block

SCA

Pleura

Ant/Post Divisions Brachial Plexus

SCA= Subclavian artery

Brachial plexus supraclavicular approach

Lateral

Medial

SCA= Subclavian artery

Longitudinal view of brachial plexus

Musculocutaneous Nerve

CB= coracobrachialis muscle  BM= Biceps muscle

Sciatic nerve

GMM
Sciatic n. ~ 10cm above popliteal fossa

Sciatic n. bifurcating to Common Peroneal and Tibial n.

Popliteal block

Femoral nerve

Other applications of U/S in anesthesia

- Cardiac assessment
- Anomalies
- Function
- Volume status
- Facilitation of spinal and epidural placement
- Gastric volume/contents assessment
What the future holds….

Vscan- Cell-phone sized ultrasound device made by GE™

Cost of equipment

- Portable ultrasound machines average between $40K-$80K
- The transducer probe is the most expensive part of the machine, one transducer can cost up to $25K alone
- Can buy or lease a machine, or some vendors “loan” equipment based on use of disposables

Reimbursement for US

- If you or your employer owns the equipment, you can submit for a facility charge for US use for procedures.
- The provider can submit a professional charge for US guidance in some circumstances.
- You must retain a permanent record (picture or digital image) of the ultrasound utilization
- Some insurers require proof of training for some types of US exams

Recommended Textbooks


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