AACPDM 2014 Pre-Course 4: B Mode Ultrasound for Muscle Hypertonia and Neuromuscular Disorders: Review of Scanning Techniques and Hands On Training

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Ultrasound Machines for Hands On Session Provided by:

— Terason
Agenda: Introduction to Ultrasound Guidance for BoNT Injections

Didactic Session

• Course Overview 5 minutes
• US Scanning Basics 20 minutes
• Comparison Of Guidance Techniques 10 minutes
• Muscle US, Neuromuscular Disorders 30 minutes
• Scanning Techniques Demonstration 15 minutes
  – Alter/Berweck
• Questions/break 15 minutes
• Hands On Scanning 150 minutes
Pre-Course 4 Agenda Continued

Lower Limb Hands On Scanning
• 60 minutes
  • Hip/Adductors
  • Hamstrings/Quadriceps
  • Calf: anterior/posterior

Upper Limb, Hands On Scanning
• 70 minutes
  – Shoulder
    • Pectoralis Major
    • Latissimus
  – Elbow
    • Biceps, brachialis, brachioradialis
  – Forearm
    • FCR, FDS, FDP, FPL
    • Pronators
Pre-Course 4 Agenda Continued

Head and Neck

• 20 minutes
• Salivary glands
• Masseter
Disclosures

• Katharine Alter
  – Consultant, Allergan
  – Consultant, Terason

• Steffen Berweck

• Florian Heinen

• Sebastian Schroeder
Ultrasound Basics to Guide BoNT Injections

• In the USA
  – BoNT injections are off label for children
    • In other countries BoNT is on label for children with CP
  – BoNT is on label in adults for many indications including
    • Spasticity: upper limb, post stroke
    • Cervical dystonia
    • Over active bladder
    • Others …..
  – All BoNTs carry a boxed warning related to the potential for distant spread, dysphagia, respiratory complications
Diagnostic Ultrasound (US) and US for Procedural Guidance

- Why should you consider using US for these procedures?
- US often provides useful information when evaluating a patient with suspected neuromuscular or musculoskeletal disorders
  - Assists in establishing or establishes a diagnosis or directing work up
- For procedural guidance
  - Correctly isolates the target for injection which is important for
    - Efficacy
    - Minimizing risk
US for Chemodenervation Procedures

• Evidence supports US guidance as more accurate localization technique for a variety of invasive procedures including chemodenervation procedures

  – Owing to
    • Direct visualization of
      – Target
      – Structures to be avoided
      – Needle location
    • Continuous needle visualization during the procedure
US Use in Clinical Practice Has Increased Exponentially

• Reduced cost of US units that
  – Provide high resolution images
  – Portable

• Access to training
  – Expertise of clinicians

• Recognition of the utility of US
Diagnostic Ultrasound

- Ultrasound is also increasingly used for diagnostic evaluations
  - Musculoskeletal disorders
  - Neuromuscular disorders
    - Muscle disease
    - Neuropathies
    - Other conditions
What you need to know to start scanning?

US BASIC PHYSICS
Ultrasound Basics:
Sound Wave Pulse Generation

• US waves(λ) are produced by piezoelectric crystals:
  – Thin device that both generates and receives sound wave pulses

• How do they do that?
Ultrasound Pulse Generation and Reception

Piezoelectric Crystals

- Convert electrical pulses into vibrations
- Converts returning vibrations back into electrical pulses
- A linear array of crystals is used to create planar images
- Returning echoes are processed to create grey scale 2D/3D/4D images
Ultrasound Equipment Basics:

• Piezoelectric crystal arrays are placed in transducers:
• Transducers
  – Determine the frequency of US waveform (\( \lambda \))
  – Frequency of US \( \lambda \) determines
    • Depth of penetration
    • Resolution
• Image processing/reconstruction
  – \( \lambda \) returning from near objects reach the transducer before those from distant objects
  – Image reconstruction is performed using Time:Distance constant or coefficient
Ultrasound: Transducer Selection

• Size/Shape of transducer
  – Linear:
    • Best for flat surfaces
  – Curvilinear:
    • Best for abdomen/pelvic/GYN
  – Hockey stick:
    • Hand
    • Small irregular surfaces

• Transducer Frequency determines
  – Depth of sound penetration
  – Resolution
Ultrasound Basics: Transducers

<table>
<thead>
<tr>
<th>MHz</th>
<th>Depth/Penetration</th>
<th>Application</th>
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<tbody>
<tr>
<td>3</td>
<td>12-20 cm</td>
<td>OB/GYN</td>
</tr>
<tr>
<td>5</td>
<td>12-15 cm</td>
<td>Deep muscles</td>
</tr>
<tr>
<td>7.5</td>
<td>8-10 cm</td>
<td>Leg</td>
</tr>
<tr>
<td>10</td>
<td>5 cm</td>
<td>Forearm</td>
</tr>
<tr>
<td>12-17</td>
<td>3.5-2 cm</td>
<td>Hand, face</td>
</tr>
</tbody>
</table>

Select transducer to match required penetration depth

- 12-17 MHz for superficial structure
  - Hand, forearm
- 3-5 MHz for deep muscles
  - Piriformis, iliacus, quadratus lumborum
- Most transducers have mixed frequencies
  - 5-3, 12-5, 15-4
Basic Concepts in Ultrasound Physics

- Depending on acoustic impedance US waves (λ) are:
  - **Reflected** at the *interface* between
    - Two tissue types or structures of different densities
    - Speed of sound traveling in different tissues
  - **Scattered** as they propagate through tissues
  - **Absorbed** traveling on to deeper structure

- Acoustic Impedance = \( \text{density} \times \text{speed of sound} \)
Appearance of echoes depends on:
Size of scatters (L) relative to the US wavelength (λ)
Ex: Wavelength of 10-MHz ultrasound = 0.15 mm

Weak scattering from blood and fluids L<< λ
Appears dark or hypoechoic

Strong echoes from “mirror-like” interfaces L>> λ
Appears bright or hyperechoic
US Basics: View convention

- Top of screen/image
  - Superficial
- Bottom of screen/image
  - Deeper structures
- Transverse view
  - Conventions vary
    - Screen left = patient right
    - Screen left = medial

Superficial

Deep

Transverse view, posterior calf
US Basics: View convention

Longitudinal view Convention

• Proximal = screen left
• Distal = screen right

Qadriceps tendon and patella

Proximal  Distal
Transducer Handling/Orientation

• To correctly orient the transducer on the patient
  – Look for a mark on one end of the transducer
  • Terason transducers mark = notch
    – The marked end = left of the display screen
  – To confirm this orientation tap one end of the transducer to confirm the orientation
ULTRASOUND PROPERTIES OF TISSUES
US Basics: Tissue Properties

- **Muscle**
  - Hypoechoic background (contractile elements/fascicles)
  - Interspersed hyperechoic bands of fibroadipose tissue
- **Long axis**
  - CT appears as parallel hyperechoic lines, less uniform than in tendon
- **Short Axis**
  - CT intramuscular tendons, aponeurosis appear as bands and streaks
US Muscle identification

• Identification of muscles is based on pattern recognition of
  – Contour lines
  – Adjacent structures
    • Bones
    • Vessels
    • Other muscles
  – Real-time
    • Use AROM/PROM to assist muscle identification
Ultrasound Properties of Glands

• Glands are distinguished by their uniform echotexture or appearance on B mode US
  – Unlike muscle which has a mixed hyperechoic/hypoechoic pattern
US Basics: Transducer Orientation

Long Axis of Transducer

Short Axis of Transducer
How to Hold the Transducer

**Correct**

Hold transducer with thumb
Index +/- middle finger
Maintain Contact with patient using
Heel of hand or 4th 5th fingers

**Incorrect**

“Free handing” the transducer
Hand is not in contact with patient
This allows the transducer to slip out of place
Limb/Muscle Orientation

Long Axis / Longitudinal

Short Axis / Transverse
Interventional MS US: Clinical Pearls

• In plane/long Axis needle view:
  – Keep needle parallel to transducer
  – Insert needle at flat angle
  – Poor needle visualization
    • Oblique position
    • Steep angle needle

• Out of plane/short axis needle view:
  – Keep needle **tip** under US beam
    • If needle **tip** is outside of US beam, visualization is lost
    • May be in untargeted structure or muscle
  – **Walk down technique**
    • Follow movement of needle tip passing through tissues planes to target
Interventional MS Ultrasound: Clinical Pearls

- **Real time injection**
- **Keep needle within the ultrasound beam**
  - If travel out side of the narrow beam needle visualization is lost
    - May not be in target structure
Interventional MS Ultrasound: Pearls of Wisdom

- Larger needles are easier to see than small needles
  - Larger needles hurt more
  - 27g hypodermic needles are easily seen
  - Non-insulated needles are visualized better than insulated. Etched Needles are also available

- Small amount of air or injectate (.2-.3 ml) helps define needle location

- Billing: In the USA, to charge/bill for US, a picture or cine-loop must be saved to document the procedure
  - Current CPT Code: 76942: Ultrasound for Needle guidance, aspiration
Chemodenervation Procedures

COMPARISON OF GUIDANCE TECHNIQUES
Traditional Localization Techniques for BoNT Injections: Palpation, EMG, E-Stim

**Advantages:**

- **Anatomic:** No equipment needed
- **EMG/E-Stim**
  - Clinician familiarity
- **Some muscles may be easily/quickly isolated**
  - Many are not
Techniques for BoNT Injections: Anatomic/EMG/E-Stim

Disadvantages

• Patient related factors
  – Anatomic variations
  – Rearrangements
    • Hypertonia
    • Contracture
    • Deformity
  – Cooperation
  – Impaired selective motor control
Localization Techniques for BoNT: EMG/Anatomic

Disadvantages

• Difficult to isolate deep/overlapping muscles

• Co contraction, mass synergy, impaired selective motor control
  – EMG signal falsely attributed to target when needle is in another muscle

• E-Stim
  – Over stimulation
    • Volume conduction can lead to errors
  – Pain from stimulation often requires sedation
Anatomic/EMG/E-stim Localization Disadvantages

Patient related factors:

Muscle size, architecture and shape all vary with age

Heinen et al
Anatomic/EMG/Estim Localization

Disadvantages

Heinen et al

GMFCS I

GMFCS III

Sonography
Diameter
Echogenicity

Muscle Size: Inversely related to impairment level
Ultrasound for Procedural Guidance

Disadvantages

• Equipment factors
  – Availability
  – Cost

• Clinician related factors
  – Lack of experience
  – Steep learning curve
  – Limited access to training specific for BoNT injections

Transverse view, proximal Thigh/Anterior
US for BoNT Injections: **Advantages**

**Improved accuracy**

– Complex/overlapping anatomy obscures muscle identification

– Small/large patients
  
  • Provides direct assessment of target
    – Depth
    – Location
    – Structures to be avoided
US for BoNT Injections: **Advantages**

- **Visualize/isolate target muscles**
  - Quickly
  - Easily
  - Accurately

- **Less painful**
  - Smaller needles

- **Pediatric patients often require no sedation**
  - Distract patients during procedure

In plane injection lateral Gastroc
US for BoNT Injections: **Advantages**

- Isolate deep muscles:
  - Iliopsoas
  - Piriformis
  - Tibialis Posterior
US for BoNT Injections: **Advantages**

- **High risk targets**
  - Avoid untargeted muscles or structures
  - Vessels/nerves/lung

- **High stakes muscles**
  - SCM
  - Middle Scalene
  - Oromandibular muscles
    - Pterygoids
US for BoNT Injections: *Advantages*

**Improved accuracy**

- When localization limited by:
  - Involuntary muscle activity
  - Co-contraction
  - Motor contro
  - Deformity
  - Post surgical changes
  - Patient cooperation
    - US does not require AROM to isolate muscle
- **Muscle identification is based on pattern recognition**
BoNT Injections: Why Use US?

Focal dystonia

- Goal: identify and target individual muscle fascicles
  - Ex: FDS digit 3 vs. 4
- US increases accuracy and decreases time to isolate correct muscle fascicles
- Reduces pain

FDS longitudinal view, mid forearm
Short axis view of needle
BoNT Injections: Why use US?

Advantages

• Non-muscle targets:
  – Salivary Glands

• Correctly isolating gland is critical to reduce the risk of dysphagia

• EMG and E-Stim are of no help
BoNT Injections: Why use US?

- **Visualize toxin injection**
  - Confirms correct muscle

- **Assess volume of injectate in muscle**
  - Reduces risk of over injection at one site
  - Minimize spread to adjacent muscles or structures
## Comparison of Injection Techniques

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<tr>
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<th>EMG</th>
<th>Stimulation</th>
<th>Sonography</th>
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<td>+/-</td>
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<td>+</td>
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<tr>
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<td>++</td>
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<td>+++</td>
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<td><strong>Future research</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+++</td>
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Ultrasound for BoNT Injection: Summary

• US is a useful technique to add to your toolbox for BoNT injections
  – Improved speed/accuracy of target localization
  – Decreased pain
  – Reduced risk of harm

• Initial learning curve is steep
  – Worth the time and effort
Ultrasound for BoNT Injection: Summary

• Localization techniques
  – Palpation
  – EMG
  – Nerve stimulators
  – Ultrasound
• All have advantages & disadvantages
• Best Strategy:
  – Be skilled in multiple techniques
US Scanning Demonstration

• How to hold the transducer....and why
• Scanning limbs/structures
• Injection Techniques
  – In plane
  – Out of plane
US EVALUATION OF NEUROMUSCULAR DISORDERS
Slides will be available online.

MUSCLE IDENTIFICATION/REVIEW
Hands on Demonstration and Scanning

- Lower Limb Muscles
  - Iliopsoas, Adductors
  - Hamstrings/Quadriceps
  - Lower leg
    - Antero-lateral calf
      - Fibularis longus, Extensor hallucis longus
    - Posterior calf
      - Gastrocnemius, Tib. Posterior, Soleus, FDL
Hands On Scanning Demonstration
Upper Limb, Head Neck

- Pectoralis Major
- Biceps/Brachialis
- Flexor Forearm

- Sternocleidomastoid
- Masseter
- Parotid/Submandibular