AACPDM 2017 Pre-Course  Hands-On Ultrasound  Course: Muscle Localization Review of Scanning Techniques and Hands On Training

Moderators
Katharine Alter MD
Steffen Berweck MD
Florian Heinen MD
Sebastian Schroeder MD

Faculty, Lecture Session:
• Katharine Alter MD
• Joline Brandenburg MD
• Mauricio Delgado MD
• Mark Gormley MD
• Florian Heinen MD
• Sebastian Schroeder MD

Faculty Hands on Session:
• Katharine Alter MD
• Rita Ayyangar MD
• Steffen Berweck MD
• Jeff Brault DO
• Bob Cooper MD
• Florian Heinen MD
• Simon Kappl MD
• Heakung Kim, MD
• Kevin Murphy MD
• Steve Nichols MD
• Sebastian Schroeder MD

Ultrasound Machines for Hands On Session Provided by:

• Fugi Films
• Terason
Acknowledgements

• Thanks to Fugi Films and Terason for supporting this program with an in-kind donation of the equipment used during the course
Disclosures:

• Katharine Alter:
  – Royalties: Demos Medical Publishing
  – Honoraria: Johns Hopkins, Dannemiller, Haymarket Medical, NANA
Disclosures: BoNT Injections for Muscle Hypertonia

• The “On-Label” status of the individual BoNT products varies by
  – Indication
    • Spasticity, dystonia, hemifacial spasm, blepharospasm, migraine, hyperhidrosis, esthetic uses etc.
  – County
  – Age of the patient
    • Children
    • Adults
    • Spasticity: upper limb, post stroke
    • Cervical dystonia
    • Over active bladder
    • Others ......

• All BoNTs carry a boxed warning related to potential distant spread/dysphagia/respiratory complications and or death
Course Overview

• Primary focus is on hands on US practice to familiarize attendees with the use of US guidance for chemodenervation

• Didactic lectures reviewing US topics and related subjects are also provided

• The following course schedule may be modified to best meet the attendees and cover the subject matter
Morning Session:  8:00-12:00

- **Course Overview**  8:00-8:05 (5 min)
- **Pre-Course Survey (voluntary)**  8:05-8:15 (10 min)

**Section I Didactic 8:15-8:55 (40 min)**
  - US Basics/comparing guidance  8:15-8:35 (20min)

- **Techniques**
  - Scanning Techniques Demo  8:35-8:50 (15 min)

- **And Injection Demonstration**
  - Questions  8:50-9:00 (10min)

**Section II Hands on 9:00-10:20**

- **Session A: Upper Limb**
  - Shoulder  9:00-9:15 (15 min)
  - Arm  9:15-9:35 (20 min)
  - Forearm  9:35-10:10 (35 min)
  - Questions  10:10-10:20 (10 min)

- **Session A Upper limb cont.**
  - Hand  10:35-10:55

- **Session B Hands On: Head Neck**
  - Salivary gland:  10:55-11:05 (15 min)
  - Oromandibular  11:05-11:20 (15 min)
  - Neck  11:20-11:35 (15 min)
  - Questions  11:35-11:40 (5 min)

- **Break 10:20-10:35 (15 min)**

- **Session C Didactic Lecture:**
  - Mauricio Delgado MD: Botulinum Toxin Update 2017
  - Questions: 5 minutes

**Lunch 12:05-1:15 (1hr 10 min)**
Afternoon Session: 1:15-5:00

Part III  1:15-1:30
• Session D: Phenol Chemodenervation Mark Gormley MD
  – 1:15-1:30 (15 min)
Session E: Lower Limb Hands On
  – Hip Girdle
    1:30-1:50 (20 min)
  – Thigh
    1:50-2:10 (20 min)
  – Calf
    2:10-2:40 (30 min)
Session F: Joline Brandenburg MD : 2:40-3:00 (20 min)
• Ultrasound Elastography
• Questions 3:00-3:05 (5 min)

• Break 3:05-3:25 min (20 min)
Session G: Hands On
• US Interventional Practice with Phantoms
  3:25-3:45 (20 min)
Part IV Heakyung Kim/Bob Cooper
  – US Guided ITB Refills
    3:45-4:00 (15 min)
• Part V Open Scan and special requests 4:00-4:40 (40 min)
• Post Course Survey (voluntary) 4:40-4:50 (10 min)
• Final Questions/wrap up 4:50-5:00 (10 min)
US for Chemodenervation Procedures

• An increasing body of evidence supports that US guidance is
  – More accurate than other localization techniques for invasive procedures
  – May improve efficacy of BoNT or chemodenervation procedures
  – Owing to
    • Direct visualization of
      – Target location/depth
      – Structures to be avoided
      – Needle /injectate location
    • Continuous needle visualization during the procedure
In Clinical Practice US Use has Increased Exponentially Owing to

- Reduced cost of highly portable US units which
- High resolution images
- Access to training
  - Expertise of clinicians
- Recognition of the utility of US
US for Diagnostic Purposes

• US is also used for diagnostic evaluation
  – Musculoskeletal disorders
  – Pain conditions
  – Neuromuscular disorders
    • Muscle disease
    • Neuropathies
    • Other conditions
  – Quantitative analysis of muscle changes using strain elastography
What you need to know to start scanning?

US BASIC PHYSICS
Ultrasound Basics:
Sound Wave Pulse Generation

• US waves($\lambda$) are produced by piezoelectric crystals:
  – Thin device that both generates and receives sound wave pulses
• How?
Ultrasound Pulse Generation and Reception

**Piezoelectric Crystals**

- Convert electrical pulses into vibrations
- Converts returning vibrations back into electrical pulses
- A linear crystal array is used to create planar images
- Returning echoes are processed to create grey scale 2D/3D/4D images
Basic Concepts in Ultrasound Physics

- Depending on a tissue’s acoustic impedance, US waves (λ) are:
  - Reflected at interfaces between:
    - 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 = density $\times$ speed of sound
US Basics

- Speed of $\lambda$ in tissue is used for location
- Reflection refraction characterize tissue
  - Water few interfaces, few echoes = black/hypoechoic
  - Mirror like surfaces of dense connective tissues and bone all echoes, bounces back = white/hyperechoic
Ultrasound Equipment Basics:

Transducers
Are available in
- Various shapes/sizes
- Different frequencies of emitted US waveform (λ)
  - Frequency of US λ determines
    - Depth of penetration
    - Resolution of the image
Resolution

Lateral: Ability to discriminate 2 side by side objects

Axial: Ability to discriminate 2 objects at different depths
Transducer Basics

Select transducer to match required penetration depth

• High frequency (12-17 MHz) for superficial structure
  – Hand, forearm
• Low frequency (3-5 MHz) for deep muscles
  – Piriformis, iliacus, quadratus lumborum
• Commercial transducers have mixed frequencies
  – 5-3, 17-5, 15-4
  – Allows scanning of structures at various depths
US Basics: View convention

- Top of screen/image
  - Superficial
- Bottom of screen/image
  - Deeper structures

Superficial

Deep

Transverse view, posterior calf
US Basics: View convention

• Transverse scans
  – How do you place the transducer on the patient?
  – Conventions vary
    • Standard cross sectional imaging
      – Screen left = patient right
    • Simplified cross sectional imaging
      – Screen left = medial
US Basics: View convention

Longitudinal view Convention

- Place the transducer on the patient so that
  - Proximal = screen left
  - Distal = screen right

Qadriceps tendon and patella

Superficial

Proximal

Deep

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 corresponds to screen left on US display
  – To confirm this orientation:
    • Tap the end of the transducer
    • Observe movement on screen to confirm 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
Ultrasound Properties of tissues

Tendon:
- Highly organized linear strands
  - Anisotropic
  - Hyperechoic
  - Fibrillar

Nerve
- Cross section:
  - Speckled appearance
  - Hypoechoic central fascicle
  - Outer hyperechoic rim
    - “Donut sign”
- Longitudinal:
  - Nerves are less fibrillar/anisotropic than tendon
  - With AROM-
    - Nerves move less than tendons
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 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

Images:
- Transverse view, proximal calf
- Transverse view, proximal anterior thigh
MS Ultrasound Basics:

- Important Artifacts
  - Anisotropy
  - Acoustic shadowing
  - Acoustic enhancement
Anisotropy: Incidence/angle of US beam

Property of tendon/muscle/nerve: Echogenicity determined by incidence/angle of US beam
Artifactualy hypoechoic if US beam is not perpendicular to imaged structure

► May mimic pathology: Ex. partial tendon tear

Illustration from Rutten M J C M et al. Radiographics 2006;26:589-604 ©2006 by Rad Society of North America
Ultrasound Artifacts: Anisotropy

• Anisotropy is useful during US imaging
• Helps distinguish tendons/nerves from surrounding tissues
  – Tendon and nerve is more anisotropic than surrounding fat
Ultrasound Artifacts: Anisotropy

- Because structures overlap in slightly different planes
  - Cannot be perpendicular to all tissues in one view/direction
- Overcome this by adjusting/rocking the transducer to image at varying angles/views
Ultrasound Artifacts: Acoustic Shadowing

- US does not penetrate all tissue types
- Bone is a dense reflector of US $\lambda$
  - An acoustic shadow occurs when all/most the $\lambda$ reflect off the surface of a tissue
  - No $\lambda$ pass on to deeper structures
  - Structures deep to this tissue cannot be imaged.
Ultrasound Artifacts: Acoustic Enhancement

- Water/fluids minimally reflect US $\lambda$
- Acoustic enhancement occurs when
  - All/most the $\lambda$ pass through a fluid filled structure to deeper tissues
  - Image deep to a fluid filled cyst is enhanced
Will be covered in the scanning demonstration

TECHNICAL SKILLS
How to Hold the Transducer

Correct

Hold transducer with thumb
Index +/- middle finger
- Maintain contact with patient
- Use heel of hand or 4th & 5th fingers

Incorrect

“Free handing” the transducer
- Hand is not in contact with patient
- Transducer may slip out of place
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**
- **US beam is narrow**
  - Only the width of a credit card
  - Not the width of the transducer
- **Keep needle within the US 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 (other than reference guides)

• **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
  – Positioning
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/Estim Localization

Disadvantages

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

- **US often distracts patients during procedure**
  - Reducing anxiety/stress

In plane injection lateral Gastroc
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
  - Others
US for BoNT Injections: 

**Advantages**

**Improved accuracy**

- When localization limited by:
  - Involuntary muscle activity
  - Co-contraction
  - Motor control
  - 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

<table>
<thead>
<tr>
<th></th>
<th>Palpation</th>
<th>EMG</th>
<th>Stimulation</th>
<th>Sonography</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>+/-</td>
<td>+/-</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Practicability</strong></td>
<td>+</td>
<td>-</td>
<td>+/-</td>
<td>++</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>+/-</td>
<td>+/-</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td><strong>Pain</strong></td>
<td>+</td>
<td>-</td>
<td>+/-</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>+/-</td>
<td>-</td>
<td>+/-</td>
<td>++</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td>+/-</td>
<td>-</td>
<td>+/-</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Future research</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+++</td>
</tr>
</tbody>
</table>
Ultrasound for BoNT Injection: Summary

• Localization techniques
  – Palpation
  – EMG
  – Nerve stimulators
  – Ultrasound

• All have advantages & disadvantages

• Best Strategy:
  – Be skilled in multiple techniques
Ultrasound for BoNT Injection: Summary

• US is a useful technique to add to your tool box 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
US Scanning Demonstration

• How to hold the transducer....and why
• Scanning limbs/structures
• Injection Techniques
  – In plane
  – Out of plane
Morning Session: 8:00-12:00

• Course Overview  8:00-8:05 (5 min)
• Pre-Course Survey (voluntary)  8:05-8:15 (10 min)

Section I Didactic 8:15-8:55 (40 min)
  – US Basics/comparing guidance  8:15-8:35 (20 min)

• Techniques
  – Scanning Techniques Demo  8:35-8:50 (15 min)

• And Injection Demonstration
  – Questions  8:50-9:00 (10 min)

Section II Hands on 9:00-10:20

• Session A: Upper Limb
  – Shoulder  9:00-9:15 (15 min)
  – Arm  9:15-9:35 (20 min)
  – Forearm  9:35-10:10 (35 min)
  – Questions  10:10-10:20 (10 min)

• Break 10:20-10:35 (15 min)
• Session A Upper limb cont.
  – Hand  10:35-10:55

• Session B Hands On: Head Neck 10:55-11:45 (50 min)
  – Salivary gland: 10:55-11:05 (15 min)
  – Oromandibular 11:05-11:20 (15 min)
  – Neck 20 min  11:20-11:35 (15 min)
  – Questions  11:35-11:40 (5 min)

• Session C Didactic Lecture:11:40-12:00
  – Mauricio Delgado MD:Botulinum Toxin Update 2017
  – Questions: 5 minutes

Lunch 12:05-1:15 (1 hr 10 min)
Section II: Hands On Upper Limb

• Shoulder:
  – Pectoralis major/minor
  – Latissimus dorsi
  – Subscapularis

• Arm:
  – Biceps Brachialis
  – Brachioradialis

• Forearm:
  – Flexor forearm muscles
    • FCR/Pronator teres
    • FDS/FDP
    • FCU/FDP
    • FPL

• Upper Limb/Forearm continued
  – Extensor forearm muscles
    • Supinator
    • EDC /ECR
    • Pronator Quadratus
  – Hand
    • Lumbricals interossei

• Head and neck
  – SCM/Scalenes
  – Masseter/Salivary gland
**Afternoon Session: 1:15-5:00**

**Part III  1:15-1:30**
- **Session D: Phenol Chemodenervation**  
  Mark Gormley MD  
  - 1:15-1:30 (15 min)

**Session E: Lower Limb Hands On**  
- Hip Girdle  
  1:30-1:50 (20 min)
- Thigh  
  1:50-2:10 (20 min)
- Calf  
  2:10-2:40 (30 min)

**Session F: Joline Brandenburg MD:**  
- **2:40-3:00** (20 min)
  - Ultrasound Elastography
  - Questions 3:00-3:05 (5 min)

**Break 3:05-3:25 min (20 min)**

**Session G: Hands On**
- **US Interventional Practice with Phantoms**  
  3:25-3:45 (20 min)

**Part IV Heakyung Kim/Bob Cooper**
- **US Guided ITB Refills**  
  3:45-4:00 (15 min)

**Part V**
- Open Scan and special requests  
  4:00-4:40 (40:min)
- Post Course Survey (voluntary)  
  4:40-4:50 (10 min)
- Final Questions/wrap up  
  4:50-5:00 (10 min)
Part III Hands on Demonstration and Scanning

**Lower Limb Muscles**
- Iliopsoas, Adductors
  - Obturator nerve
- Hamstrings/Quadriceps
- Lower leg
  - Antero-lateral calf
    - Fibularis longus, Extensor hallucis longus
  - Posterior calf
    - Gastrocnemius, Tib. Poster, Soleus, FDL, FHL

**Interventional Practice/Open Scanning**
- Phantom Demo and Practice
  - In-plane
  - Out of plane
- Open Scan/Special Requests
  - Review previously scanned regions
Ultrasound for Chemodenervation Procedures: Summary

• All guidance techniques have advantages & disadvantages
• Best Strategy:
  – Be skilled in multiple techniques
• The goal of this course was to provide attendees with a
  – Review of US and scanning techniques
  – Hands on practice for
  – Pattern recognition
  – Muscle/structure identification
  – Procedural guidance skills
• Let’s see how we did:
  – Post course survey