AACPDM 2015 Pre-Course 4 Hands-On Ultrasound Course: Muscle Localization, review of Scanning Techniques and Hands On Training

**Moderators**
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**Faculty, Lecture Session:**
- Katharine Alter MD  
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**Faculty Hands on Session:**
- Katharine Alter MD  
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- Simon Kappl MD  
- Heakung Kim, MD  
- Kevin Murphy MD  
- Steve Nichols MD  
- Sebastian Schroeder MD

- Ultrasound Machines for Hands On Session Provided by:

  — Terason

[NIH National Institutes of Health Clinical Center](#)
Disclosures: BoNT Injections for Muscle Hypertonia

• 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 potential distant spread/dysphagia/respiratory complications and or death
AACPDM Pre-course Agenda

• Morning Session: 8:00-12:00
• Course Overview 8:00-8:05 (5 min)
• Section I Didactic 8:05-8:55 (50 min)
  – US Basics 15 min
  – Comparing Guidance Techniques 10 min
  – Scanning Techniques Demo 10 min
  – Injection Demonstration 10 min
  – Questions 5 min

• Section II Hands-On 8:55-10:00
• Session: Upper Limb 90 minutes
  – Shoulder 8:55-9:10 (15 min)
  – Arm 9:10-9:30 (20 min)
  – Forearm 9:30-10:00 (30 min)
  – Questions 10:00-10:10 (10 min)
• Break 10:10-10:30 (20 minutes)
• Upper limb cont. 10:30-10:50
  – Hand (20 min)
• Section III 10:50-12:00 (70 min)
• Hands on Head and Neck 11:00-12:00
  – Salivary gland: 11:00-11:20 (20 min)
  – Oromandibular 11:20-11:40 (20 min)
  – Neck 30 min 11:40-11:55 (15 min)
  – Questions 5 minutes
• Lunch 12:00-1:15 (1hr 15 minutes)
AACPDM Pre-Course Agenda

- **Afternoon Session:** 1:15-5:00
- **Part IV** 1:15-1:30
  - Botulinum Toxin Update 2016 FDA Approval Pediatrics
    - Mauricio Delgado MD (15 minutes)
- **Part V Hands-On** 1:30-3:05
- **Lower Limb Hands On**
  - Hip Girdle 20 min 1:30-1:50
  - Thigh 20 min 1:50-2:10
  - Calf 30 min 2:10-2:40
- Phenol Chemodenervation Procedures 2:40-3:00
  - Mark Gormley MD
- **Questions 5 min** 3:00-3:05
- **Break** 3:05-3:25 min (20 min)
- **Part VI**
  - Hands On: Nerves 20 min 3:25-3:45
- **Part VII**
  - US Guided ITB Refills 3:45-4:00
    - Drs. Kim and Cooper (15 min)
- **Part VIII Open Scan and Special Requests** 4:00-4:45
- **Final Questions/and Wrap Up** (15 min)
Why Should you Learn a New Technique for Chemodenervation?
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 increasing used for diagnostic evaluation
  - Musculoskeletal disorders
  - Pain conditions
  - Neuromuscular disorders
    - Muscle disease
    - Neuropathies
    - Other conditions
Ultrasound Imaging:
Selective sparing of Semitendinosis
Preferential involvement in erector spina

Directed further work up
DX: LamininAC CMD
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 ($\lambda$) 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 = $\text{density} \times \text{speed of sound}$
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

- Piezoelectric crystal arrays are placed within a transducer
- Transducers are available in:
  - Various shapes/sizes
  - Different frequencies of emitted US waveform (\( \lambda \))
  - Frequency of US \( \lambda \) determines:
    - Depth of penetration
    - Resolution of the image
US Image Resolution Determined by Spatial Resolution = Minimum Separation between Distinct Structures

Determined by sound wave frequency
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: Transducer Selection

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

• Specialty transducers
  • Intra-cavitary
  • Cardiac
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

Distal

Deep
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

![Parotid Gland](image1.png)

![Masseter, Longitudinal View](image2.png)
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

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
Artificially 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 λ
- Acoustic enhancement occurs when
  - All/most the λ pass through a fluid filled structure to deeper tissues
  - Image deep to a fluid filled cyst is enhanced
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
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
• 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
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
Patient related factors:

Muscle size, architecture and shape all vary with age

Heinen et al
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

![Sternocleidomastoid Transverse Scan](image)
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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<th>Palpation</th>
<th>EMG</th>
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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 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
US SCANNING DEMONSTRATION
Lower Limb Hands on Scanning,

SECTION II
Lecture and Demonstration

BOTULINUM TOXINS UPDATE 2016
Upper Limb Scanning, Hands on

SECTION IV
MSK changes with Rehab in brain injury

SECTION V
SECTION VI

Head and Neck Hands on Scanning
Hands on Scanning: Open scan time, special requests

SECTION VII
US Scanning Demonstration

• How to hold the transducer....and why
• Scanning limbs/structures
• Injection Techniques
  – In plane
  – Out of plane
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. Posterior, Soleus, FDL, FHL

Upper limb

- Shoulder Girdle
  - Pectoralis Major
  - Latissimus dorsi/subscapularis
- Arm
  - Biceps/Brachialis
  - Brachioradialis
- Flexor Forearm
  - FCR, FCU, FDS, FDP, FPL
  - Pronators
- Hand
Hands On Scanning Demonstration

Head Neck

- Sternocleidomastoid
- Levator Scapulae
- Masseter
- Parotid/Submandibular