Pre-Course 4 Ultrasound Review for Chemodenervation Procedures: AACPDM 2013

Moderators
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Faculty, Lecture Session:

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• Katharine Alter MD
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• Bob Cooper MD
• Christine Jansen MD
• Florian Heinen MD
• Heakung Kim, MD
• Steve Nichols MD

• Ultrasound Machines for Hands On Session Provided by:

  – Sonosite
Agenda: Introduction to Ultrasound Guidance for BoNT Injections

Didactic Session

• US Basics 20 minutes

• Scanning Techniques Demonstration 10 minutes
  – Alter/Berweck

• Lower Limb Muscle Review/Scanning 85 minutes
  • Hip/Adductors
  • Hamstrings/Quadriiceps
  • Calf: anterior/posterior

• Questions/Wrap up: 5 minutes
Pre-Course 4 Agenda Continued

• Break 15 minutes
• Upper Limb Muscle Review/Scanning 85 minutes
  – Pectoralis/Latissimus Dorsi
  – Biceps/brachialis/brachioradialis
  – Flexor forearm
• Head and Neck Review/Scanning 25 minutes
  – Salivary glands/Masseter
  – Sternocleidomastoid
• Wrap up/questions 5 minutes
Disclosures

• Katharine Alter
  – Consultant, Allergan
  – Speakers Bureau, Ipsen, Neurotoxins Institute

• Steffen Berweck
• Robert Cooper
• Florian Heinen
• Steven Nichols
Ultrasound Basics to Guide BoNT Injections

• In the USA
  – BoNT injections are off label for children
    • In other countries BoNT is on label
  – 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
BoNT Treatment

• Correctly isolating the target for injection is important for
  – Efficacy
  – Minimizing risk
  – Reducing
    • Required dose
    • Side effects
Traditional Localization Techniques for BoNT Injections: Palpation, EMG, E-Stim

**Advantages:**

- Anatomic: No equipment needed
- EMG/E-Stim
  - Clinician familiarity
- Some muscles are easily/quickly isolated
- Others are not
Localization Techniques for BoNT:
EMG/Anatomic

Disadvantages

• Difficult to isolate deep/overlapping muscles
• EMG Signal falsely attributed to target
  – Cocontraction, mass synergy
  – Impaired selective motor control
• E-Stim
  – Volume conduction can lead to errors
  – Pain from stimulation often requires sedation
Techniques for BoNT Injections: Anatomic/EMG/E-Stim

Disadvantages

• Patient related factors
  – Anatomic variations
  – Rearrangements
    • Hypertonia ➔ contracture ➔ deformity
  – Cooperation
  – Impaired selective motor control
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

GMFCS I

Heinen et al

Sonography
Diameter
Echogenicity

GMFCS III

Muscle Size: Inversely related to impairment level
Ultrasound and 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
Ultrasound Guidance 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
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 control, patient cooperation
    - US does not require AROM to isolate muscle
- **Muscle identification is based on pattern recognition**
US for BoNT Injections: **Advantages**

**Improved accuracy**

- When localization limited by:
  - Involuntary muscle activity
  - Co-contraction
  - Motor control, 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
Ultrasound Guided BoNT Therapy Why use Ultrasound?

• Quickly, accurately visualize target muscle
  – With or without PROM or AROM
  – in patients with co-contraction, poor motor control
• Reduced pain
• Visualize toxin injection
  – Avoid volume overload of muscle/injection site
    • Reduces spread to contiguous muscles/structures
• Accurately measure post injection change in muscle
  – Cross sectional area, thickness
• Distracts patient during the procedure
Ultrasound for BoNT Therapy

• For many reasons, clinicians who use US consider it to be a more/the most accurate localization method for BoNT
  – Owing to
    • Direct visualization of target structure and needle placement
    • Image quality
    • Access to portable US systems
    • Expertise of clinicians
## 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>
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<tr>
<td><strong>Pain</strong></td>
<td>+</td>
<td>-</td>
<td>+/-</td>
<td>+++</td>
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<tr>
<td><strong>Speed</strong></td>
<td>+/-</td>
<td>-</td>
<td>+/-</td>
<td>++</td>
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<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>
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US BASIC PHYSICS
Ultrasound Basics: Sound Wave Pulse Generation

• US waves (\(\lambda\)) are produced by piezoelectric crystals:
  – Thin device that both generates \textit{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

• Most Transducers use a range of frequencies
  – 3-5 MHz
  – 5-10 MHz
  – 6-12 MHz
## Ultrasound Basics: Transducers

<table>
<thead>
<tr>
<th>MHz</th>
<th>Depth/Penetration</th>
<th>Application</th>
</tr>
</thead>
<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>5cm</td>
<td>Forearm</td>
</tr>
<tr>
<td>12-17</td>
<td>3.5-2cm</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**
  - 3-5, 7-12 etc
Basic Concepts in Ultrasound Physics

- Depending on acoustic impedance US waves ($\lambda$) 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 = $\text{density} \times \text{speed of sound}$
US Basics

- Speed of $\lambda$ in tissue is used for location
- Reflection refraction characterize tissue
- Water few interfaces, few echoes = black
- Air, bone all echoes, bounces back = white
Appearance of echoes depends on:
Size of scatters (L) relative to the US wavelength (λ)
Ex: Wavelength of 10-MHz ultrasound = 0.15 mm

“Speckle” from scattering in tissue.
L ~ λ

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 image is superficial
  – i.e. skin

• Bottom deeper structures

• Transverse view
  – Conventions vary
    • Right always to patient right
    • Medial always to right

• Longitudinal view
  – Left proximal
  – Right distal

Transverse view, posterior calf
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 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
Scanning Tips/Techniques: Injection Techniques

In Plane: Needle Inserted Along Long Axis of Transducer

Out of Plane: Needle Inserted Across the Short Axis of the Transducer
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 los
    • 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 needles are easily seen particularly in an in plane view
  - Non-insulated needles are visualized better than insulated. Etched Needles are also available
- Small amount of air (.2-.3 ml) helps define needle location
- Agitate injectate: increases reflection from bubbles
  - Agitating may denature the toxin
- Billing: In the USA, to charge/bill for US, a picture or cine-loop must be saved to document the procedure
- Billing Code: 76942: Ultrasound for Needle guidance, aspiration
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

FCR
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
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
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 hallicus 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