2016 Botulinum Toxin Therapy Update: Focus on Limb Dysfunction
Ultrasound Guidance for Chemodenervation and Pain Procedures

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Disclosure

- Dr. Alter has disclosed that she has received Honoraria from Haymarket Medical, Johns Hopkins University, Dannemiller and royalties from Demos Medical Publishing.
Guidance Techniques for Chemodenervation

- Comparison of available guidance techniques for chemodenervation procedures
  - Advantages/disadvantages
- Review of US Physics/technical skills for procedural guidance
- Examples of US guided chemodenervation procedures
  - Nerve blocks
  - Botulinum toxin injections
Chemodenervation Procedures

- Nerve blocks
  - Anesthetic/diagnostic
  - Neurolytic
    - Phenol/alcohol

- Chemodenervation
  - Botulinum toxin (BoNT)
  - Motor point blocks
    - Phenol/alcohol

Invasive Medical/Surgical Procedures

- All invasive procedures involve risk
  - Infection
  - Injury to
    - Nerves/Vessels
    - Organs
    - Muscles
  - Injection of untargeted structures
  - Anesthesia risks
Guidance Techniques for Chemodenervation Procedures

- Accurate targeting is important for
  - Efficacy
  - Minimizing risk
  - Reducing dose of agent/drug
  - Adverse events
- Options
  - Anatomic/palpation
  - EMG, E-Stim
  - Imaging: US, Fluoroscopy

Procedural Guidance Techniques for Invasive Procedures/Injections

Anatomic/Palpation

Advantages:

- No equipment needed
- Reference guides are available
- A few structures may be isolated
  - Easily
  - Quickly
  - Accurately

EMG Guidance for Chemodenervation Procedures

Advantages

- Widely available
- EMG units are relatively inexpensive
- Clinician experience
- EMG:
  - Provide information on muscle activity to guide treatment
  - Auditory feedback of muscle activity

O’Brien CF. Injection techniques for botulinum toxin using electromyography and electrical stimulation. Muscle Nerve, 1997; S6, S176–S180,
E-Stim Guidance for Chemodenervation Procedures

Advantages

- E-Stim provides
  - Provides visual feedback of muscle contraction confirming location in muscle
  - Can be used when:
    - Co-contraction, mass synergy limit usefulness of EMG
    - Patients are sedated
Localization Techniques: Anatomic/EMG/E-Stim Guidance

Disadvantages

- Difficult to palpate or deep/overlapping
  - Muscles
  - Joints
  - Other structures
- Difficult to position patients as recommended in guide books
  - Limits accuracy of this technique for localizing muscles

Localization Techniques for BoNT: Anatomic/EMG/E-Stim

Disadvantages

- Anatomic variations, rearrangements
  - Hypertonia
  - Contracture
  - Deformity
  - Surgery
- Limited patient cooperation
- Impaired selective motor control
- Pain
  - Monopolar injection needles are more painful than hypodermic needles of a similar size

Henzel, Munin et al PMR 2010 Surface vs. US Localization to Identify Forearm Flexor Muscles for BoNT,
Localization Techniques:

**EMG**

**Disadvantages**

- Only useful for muscle targets
- Signal may be falsely attributed to target when needle is in another muscle
  - Co contraction, mass synergy
  - Impaired selective motor control

BoNT Induced Dysphagia in Cervical Dystonia: Comparing US and EMG: Hong JS et al 2012
Localization Techniques: E-Stim

E-Stim Disadvantages

- Only useful for nerve/muscle targets
- Difficult to position patients
- May be difficult to isolate target
  - Deep nerves/muscles
  - Overlapping anatomy
- Volume conduction can lead to localization errors
- Pain from stimulation
  - Requires sedation in children

Limitations, Anatomic/EMG/E-Stim: Size and Age of Patient

Difficult to judge depth of muscle
  - Obese patients
  - Pediatric patients
Age related variations and changes in:
  - Muscle size
  - Architecture
  - Shape
Limits estimating muscle orientation, position, and depth

Photos From Heinen F. et al.

12 year old male
5 year old female
11 year old female
29 year old male

FCR Transverse view – Examples/
Limitations Anatomic/EMG/E-Stim: Impairment Level

GMFCS I

GMFCS III

Sonography Diameter Echogenicity

Muscle Size: Inversely related to impairment

Photos from Berweck, Heinen, Schroeder

GMFCS- Gross Motor Functional Classification Scale

Photos From Heinen et al.
Imaging Based Guidance for Chemodenervation Procedures

- Imaging based guidance options
  - MRI
  - CT
  - Fluoroscopy
  - Ultrasound
Disadvantages of MRI, CT, Fluoroscopy

- Limited access
  - Radiology, OR suite
- Cost
- Radiation exposure with CT, Fluoroscopy
- Limited bore size for MRI
  - Special equipment required

Ultrasound for Procedural Guidance

Advantages

- Availability
- Portability
- Cost of equipment
  - Image resolution
    - Similar to MRI (0.1mm)
- Continuous real-time guidance
- No radiation exposure
- Patient acceptance

US for Procedural Guidance: Advantages

**Improved Accuracy**

- Complex/overlapping anatomy
  - Obscures structure identification
  - Small/large patients, children
- US allows visualization of
  - Target location
  - Target depth
  - Structures to avoid

Forearm muscles
US for Procedural Guidance: Advantages

- Continuously visualize target and needle
  - Quickly
  - Easily
  - Accurately
- May be less painful
  - Smaller needles
- Distracts patients
  - Pediatric patients often require no sedation
US for BoNT Injections: Advantages

- Improved accuracy when localization is 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

- Identify structures to avoid
  - Nerves
  - Vessels
  - Organs
  - Non-targeted muscles
- Which often accompany the target structure
Ultrasound for Botulinum Injections, Advantages: Focal Dystonia

- Isolate Individual muscle fascicles
  - Ex: FDS digit 3 vs. 4
- US increases accuracy and speed of identifying correct muscle fascicles
- Reduces pain/discomfort

Longitudinal Muscle View
Short axis view of needle
High Risk Muscles: SCM

Transverse View, Anterior Neck

Needle Inserted Under EMG Guidance, Checked By US

Needle Inserted into Carotid Artery
US for BoNT Injections: Advantages

- **Visualize injectate**
  - Confirms correct site
  - Provides info on volume of injectate/distension of muscle
    - Reduces risk of over injection at one site
  - Minimizes spread to adjacent muscles or structures


Video from Michael Munin
US for Procedural Guidance: Botulinum (BoNT) Toxin Injections

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

Ultrasound for Chemodenervation: Summary

• Localization techniques
  – Palpation
  – EMG
  – Nerve stimulators
  – Ultrasound
• All have advantages & disadvantages
• Best Strategy:
  – Be skilled in multiple techniques
  – Be aware of
    – The limitations of each technique
    – Evidence supporting/refuting the accuracy of the various techniques

## Comparison of Guidance 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>
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<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>
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<tr>
<td><strong>Speed</strong></td>
<td>+/-</td>
<td>-</td>
<td>+/-</td>
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<tr>
<td><strong>Evaluation</strong></td>
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<td>-</td>
<td>+/-</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Future research</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+++</td>
</tr>
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</table>

Resources

- Munich Ultrasound Course
- www.munichultrasoundcourse.com
- MUC - Munich Ultrasound Course.
- Focus on sono-anatomy | targeting the muscle | children & adults. A.
- Sebastian Schroeder 1*, Steffen Berweck 2*, Urban M.
Ultrasound Basic Physics
US 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?
US Pulse Generation and Reception

**Piezoelectric Crystals**

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

Ultrasound Basics: Transducers

- Transducers determine sound wave frequency
- Frequency determines
  - Depth of sound penetration
  - Resolution
- Transducers come in a variety of sized, shapes

## 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 based on 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
US Basics: Grey Scale Correlates with strength of reflected $\lambda$

- **Hyperechoic** = Bright image:
  - When US reflects off strong “mirror like” surfaces
  - Most of the $\lambda$ are reflected back to transducer = bright signal
    - Lower water content tissues
    - Ex: Fibroadipose, connective tissue, tendon

- **Hypoechoic** = Darker image:
  - Fewer $\lambda$ reflected back to transducer = high water content tissues
    - Ex: Muscle, cartilage, fluids

Imaging Basics
US Basics: View Convention

- **Top of image** = superficial structures
  - i.e. skin
- **Bottom of image** = deeper structures
- **Longitudinal view:**
  - Hold transducer so
    - Screen Left = proximal
    - Screen Right = distal

US Basics: Transverse View Convention

- Top of image: superficial
  - i.e. skin
- Bottom deeper structures

Transverse view
- Conventions vary
- Simplified System:
  - Screen Left side = medial patient
- Standard Cross Section:
  - Screen Left = Patient right
- Others:
  - Screen left oriented to patient left
Technical Skills
Technical Skills

- Hold the transducer between the thumb, index and 2nd finger
  - Stabilize hand against the patient using 4th/5th fingers or heel of your hand
    - Avoid slipping out of position
US Technical Skills

- Completely scan/image the region of interest prior to procedures
- US beam is narrow
  - Thinner than width of transducer
    - Width of a credit card
  - To fully image a structure, identify target, site for injection SCAN
    - Proximal -distal
    - Medial-lateral
  - Determine best plane for injection

Procedural Skills

In Plane injection
- Needle viewed in long axis
  - Entire needle visualized

Out of plane
- Needle viewed in short axis
  - Hyperechoic dot

Ultrasound Guidance for Nerve Blocks and BoNT Injections

Examples
SCM, Longitudinal, In-plane Injection
US Guided Tibialis Posterior Injection

Tibialis Posterior

- Origin: Posterior interosseous membrane and adjacent tibia and fibula
- Insertion: Tuberosity of navicular and adjacent medial cuneiform
- Innervation: Tibial nerve
- Action: Foot inversion and plantarflexion, medial arch support during gait
Flexor Digitorum Superficialis

(Transverse View)

Origin: Humero-Ulnar Head; Medial epicondyle of humerus and coronoid process
Radial Head: Radius

Insertion: Four tendons: palmar surface of distal phalanges II-V

Innervation: Median nerve

Action: Proximal interphalangeal and metacarpophalangeal joint flexion of fingers II-V, wrist flexion

Injection is performed with forearm in supination

Summary/Conclusions

- US requires learning a new set of skills and the learning curve is steep
- Despite these disadvantages clinicians should consider adding US guidance to their clinical toolbox
  - As an add on technique to traditional methods
  - As a stand alone guidance technique
A variety of guidance techniques are used by for invasive procedures

Clinicians should be aware of the advantages and disadvantages of these techniques

B mode US provides direct visual guidance of the position/depth of the target and real-time information about the needle location

– Evidence supports increased accuracy of US over the other available techniques
Save the Date!

TOXINS 2017

Basic Science and Clinical Aspects of Botulinum and Other Neurotoxins

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