Chemodenervation Using Ultrasound Guidance

Michael C. Munin, M.D.
Professor
Department of Physical Medicine and Rehabilitation
University of Pittsburgh School of Medicine
Outline for Discussion

• Why Learn About Ultrasound Localization?
• Machine Settings: Basic controls to understand
• Transducer Pearls
• Injection Techniques
• Case Examples
• Outcome Studies
Why Use Ultrasound (US) in Chemodenervation?

• Botulinum toxins (BTX) yield dose dependent decrease in spasticity and strength
• For endocytosis of BTX, must be intramuscular and (ideally) near motor end plates
• Studies have shown treatment with BTX does not always increase upper-limb motor function after stroke
  – BotULS Multi-center trial *Stroke* 2011
Why Use Ultrasound (US) in Chemodenervation?

• If botulinum toxin injections improve function, why have clinical trials not shown this consistently?
• Inappropriate outcome measures
• Inappropriate patient selection
• Inappropriate BTX injection protocol especially localization
Limitations Without Ultrasound

- EMG needle accuracy in cadavers using surface landmark localization and blind needle placement can be unreliable. 
  Haig 2003 Archives PMR

- Difficulty using surface landmarks based on normals or cadavers when full ROM not possible due to contracture.

- 3-dimensional structure may be distorted or obscured from severe muscle atrophy and fibrotic tissue replacing muscle.
Limitations Without Ultrasound

• Goal of injection: Keep injectant in fascial planes for endocytosis of toxin
• While toxin transported in retrograde fashion via neurons, keeping injectant within targeted muscle gives best opportunity to maximize outcome
• In forearm, toxin may spread causing difficulty with selected injections i.e. FDS of digit 3 and 4 only
• **US can ensure that injectant stays within correct fascial borders and does not penetrate neurovascular structures**
US Advantages vs. EMG/Nerve Stim

- **With EMG guidance:**
  - Active motor unit potentials or insertional activity
  - Don’t know where generator is coming from
  - Surprising how far injectant can spread

- **With Nerve Stimulation:**
  - May be stimulating nerve branch before target muscle so injectant deposited in another muscle
  - Even if stimulating within target muscle, no idea on depth or where the injectant spreads out
  - Painful with multiple needle sticks; hard to find target
Machine Settings: Basic Controls to Understand
US Machine Settings: **Gain**

- Compensates for attenuation (a reduction in sound amplitude) as waves travel deep into body
- Intensity of returning signals amplified so that displayed image is brighter and more visible on the screen
- Gain makes entire image brighter or muted
- \( \text{Gain} = \text{Brightness} \)
US Machine Settings: Depth

• Right side of screen shows scanning depth in cm
• For superficial structures, use highest magnification (Low scanning depth ≈2cm, ↑Frequency 10 to 18Mhz)
• For deeper structures, less magnification (Higher scanning depth ≈5cm, ↓Frequency 5 to 8Mhz)
• Depth = Magnification
US Settings: Focal Zone

• Regardless of depth, focal zone tells machine to highlight a certain region
• Modern machines provide electronic focusing (Focusing = Focal Zone)
• For example, if total scanning depth is 3cm, may want to highlight structures at 1.5cm
• It is important to place the Focal Zone at or slightly below level of target structure of interest
Compounding

• Most machines have feature built-in. Older machines may not have this feature

http://www.usra.ca/
US Settings: Doppler

- Can be standard Doppler or Power Doppler
- Very useful to identify blood vessels while injecting
- Power Doppler more sensitive to differentiate vascular structures
- Std Doppler indicates flow direction, but not required in chemodenervation
Transducer

- Key piece of equipment for US procedures
- Frequency—10 MHz to 13 MHz best for most chemodenervation
- Design—Some are easy to hold during injections. Look at different manufacturers for personal preference
- Sterility—For chemodenervation absolute sterile conditions are not required but...
Transducer Pearls

• I wipe skin with alcohol and use sterile US gel packs
• US gel is bacteriostatic; others use non-sterile gel
• For our clinics where US is used on multiple consecutive patients, transducer cover recommended
• I use cheap non-sterile condoms as barrier to blood that can easily smear across transducer
• Important: Place non-sterile gel inside condom to get an image!
• Special cleaners are suggested to wipe the transducer between patients i.e. PDI Sani-cloth
Transducer Alignment

- Refers to sliding transducer to follow course of target
- Needle can approach target in 2 directions
  - Parallel = longitudinal = in plane
  - Perpendicular = axial = out of plane
- Must understand these concepts in chemodenervation!
In Plane Approach

- Entire needle length visible including tip
- Deep structures and nerve blocks are best for this technique
- Beam Steer feature brightens entire needle length
- If many surrounding structures in path, not best approach
- Useful for pronator teres and forearm extensors, anterior thigh muscles, calf muscles and phenol injections
In Plane Approach

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In Plane Injection to Pronator Teres

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Out of Plane Approach

• Surrounding structures best seen in this view
• Important to slide transducer along shaft of needle to identify needle tip
• Do not see entire needle length
• Needle tip and shaft in cross section appear as hyperechoic white dot or shadow

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Out of Plane Flexor Carpi Radialis

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Tilting Transducer

- Helpful in out of plane view
- If tip goes past or in front of transducer, tilting will aim beam at tip
- Helps resolve anisotropy (a change in nerve echogenicity with the angle of incidence)
Orientation of US and Patient

• For chemodenervation transducer is perpendicular to injected limb
• Screen should be oriented as you are looking at patient
• EXAMPLE: If injecting left forearm, US screen should be in front of injector and behind the arm
• Injector sees ulnar left screen and radial right screen
• For parallel positions, it is customary to have cephalad (superior) left of screen and caudal (distal) to right
Orientation of US and Patient

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Ergonomics During Injections

BAD

GOOD

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Learn US Muscle Patterns
US Muscle Patterns

- For PQ, transducer is on volar distal forearm
- Injection begins at dorsal distal forearm and moves to volar direction
- Needle would come from bottom up
Top 10 List for US in Chemodenervation

1. Orient patient and US properly
2. Scan area to identify target structures and anatomy
3. Pick injection path that does not cross another muscle
4. Look for familiar patterns
   --Pronator teres/FCR   --FDS2 & 3 to median nerve
Top 10 List for US in Chemodenervation

5. May use passive movement to confirm muscle
6. Determine in plane or out of plane approach
7. Ensure nerve or vasculature clear of path. Power doppler?
8. Slowly advance gently pertubating skin to view needle movement
9. Confirm tip is within target muscle
10. See ‘blush’ and keep injectant within target muscle
US Injection Pearls

- Know how muscle looks different than nerve, gland and vessels
- Realize that with spasticity, extracellular matrix increases
- Myofibrils have less cross sectional area and more fibrous tissue; these changes can make muscle look brighter
- Muscles can be injected in multiple locations given their length and width
- Goal is to inject directly without crossing other muscles
CASE EXAMPLES USING US FOR CHEMODENERVATION
25 yo F MS, ankle injury with spastic inversion. Targeting Med Gastroc
Accuracy of Injections to Gastrocnemius in Stroke Patients  
Picelli 2012 J Rehabil Med

- 81 patients with toxin injections to calf muscles
- Randomized to palpation or Estim; confirmed with US
- Med Gastroc Depth: 13mm vs. Lat Gastroc 10mm
- 92% accuracy in Med Gastroc both methods combined; 79% accuracy Lateral Gastroc palpation vs. 90% estim
- Even with Estim 10% error rate
- Errors go to Soleus or Subcutaneous tissue
Accuracy of Manual Needle Placement in Fresh Cadavers
Schnitzler Muscle Nerve 2012

• 121 practitioners asked to inject gastrocnemius with surface anatomy only
• 30 Cadavers with verified injection location
• Only 43% injections successful
• 2/3 of failed injections too deep into Soleus
• 1/3 of failed injections in superficial fat
• Result unrelated to injector experience
Botulinum Toxin A Injection into Calf Muscles for Treatment of Spastic Equinus in Cerebral Palsy: A Controlled Trial Comparing Sonography and Electric Stimulation

Kwon AJPMR 2010

- N=30 children randomized to US vs Estim
- Sonography-guided group significantly better with Physician's Rating Scale (gait pattern and hindfoot position; maximum foot/floor contact during stance)
- MAS and Tardieu not different with techniques
44 yo F Spastic Dystonia 3rd, 4th PIP
Comparison of Surface and Ultrasound Localization to Identify Forearm Flexor Muscles for Toxin Injections
Henzel PMR Aug 2010

- Compared surface localization using FB landmarks from Delagi to US localization for 18 subjects with upper limb spasticity
- Goal was to obtain optimal injection site defined as direct injection without crossing muscles or nerves/vessels
Comparison of Surface and Ultrasound Localization to Identify Forearm Flexor Muscles for Toxin Injections
Henzel PMR 2010

- Significant proximodistal differences in FPL and Pro Teres location; FCR trended toward significance
- For lateral coordinates, significant differences in FDS3 and FCR location. FDS2 and FDS4 trended significant
49 yo F Cervical Dystonia
Elimination of dysphagia using US guidance for botulinum toxin injections in cervical dystonia

Hong Oct 2012 Muscle and Nerve

- Literature 10 to 40% rate of dysphagia all toxins
- 5 females with EMG only guidance
- **34.7% rate of dysphagia** over 98 injection sessions
- 200 to 283 units of onabotulinumtoxinA (range)
- 1 patient averaged 13,667 units of rimabotulinumtoxinB
- Good clinical outcome but side effects were causing morbidity with patients considering discontinuing treatment
Elimination of dysphagia using US guidance for botulinum toxin injections in cervical dystonia

Hong Oct 2012 Muscle and Nerve

• Speelman 1995 showed EMG guidance useful to decrease side effects such as dysphagia
• Underestimation of needle depth with EMG since deeper muscles will generate motor unit potentials: Can not distinguish from SCM units
• Results in unintentional remote spread into scalenes and pharyngeal muscles
• 0% rate of dysphagia with US guidance over 27 injection sessions
Elimination of dysphagia using US guidance for botulinum toxin injections in cervical dystonia

Hong Oct 2012 Muscle and Nerve

- Subset of cervical dystonia patients may present with hypertrophied SCM
- We measured total depth from skin to end of SCM 0.8cm in subjects (similar to age and gender matched controls)
- Our patients did not have hypertrophy possibly due to repeated injections as a cause for muscle atrophy
- During US-guided injections, 1 injection site only since direct visualization of injectant within muscle
Take Home Points

• US has a role in chemodenervation procedures
• Understand in plane vs. out of plane technique
• Proper orientation of patient to US machine
• Pattern recognition to find target and optimal injection site while avoiding neurovascular structures
• Keep injectant within fascial borders
Questions?

Thank you!