

Peripheral Nerve Stimulation: From Torpedo Fish to StimRouter

Einar Ottestad, MD, FIPP, CIPS

President- WAPMU

Stanford University School of Medicine



Disclosure

- No conflicts of interest

PNS predated SCS

‘On October 9, 1965, Dr. Wall and one of us (Dr. W.H. Sweet) implanted a pair of silastic ring platinum electrodes around the ulnar and another pair around the median nerve in the arm carrying the wires out of the skin at the mid- forearm. On the median nerve 0.1- ms pulses at 100/s and 0.6 V provoked a pleasant tingling in the lateral three fingers and corresponding hand and stopped the pain in the medial three fingers and hand as well as tenderness in the third finger and palm.’

*White JC, Sweet WH: Pain and the Neurosurgeon:
A Forty-Year Experience. Springfield, Thomas, 1969, pp 894–899.*

Troubles

- Off-label
- Tunneling to the IPG
- Lead tethering and migrations
- Anchors, multiple incisions
- Lengthy operating times
- Multiple sites for wound Infection
- Programming problems

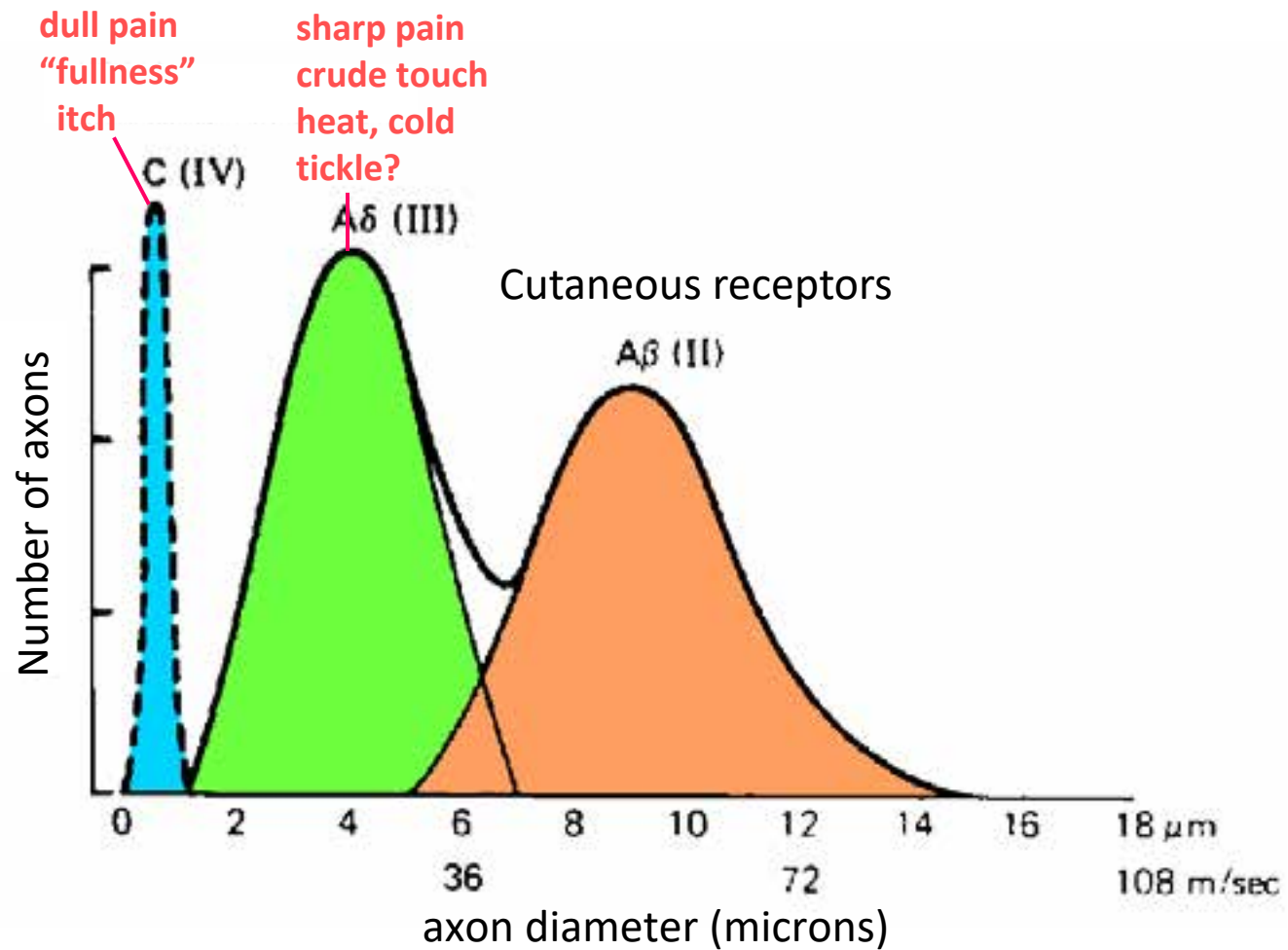


Why PNS Survived?

- Philosophically it makes more sense targeting specific injured nerve rather than “blasting” entire region with SCS
- Responders tend to remain responders for very long and need to use PNS less and less
- Functional benefits

Mechanisms of Action

- Central: spinothalamic inhibition, central neurochemical mechanisms, trigeminovascular system
- Peripheral: subcutaneous electrical conductance, dermatomal and myotomal stimulation, sympathetic stimulation, local blood flow alteration, peripheral neurochemical mechanisms
- Main mechanism: selective stimulation of A-beta fibers



Take Home Messages

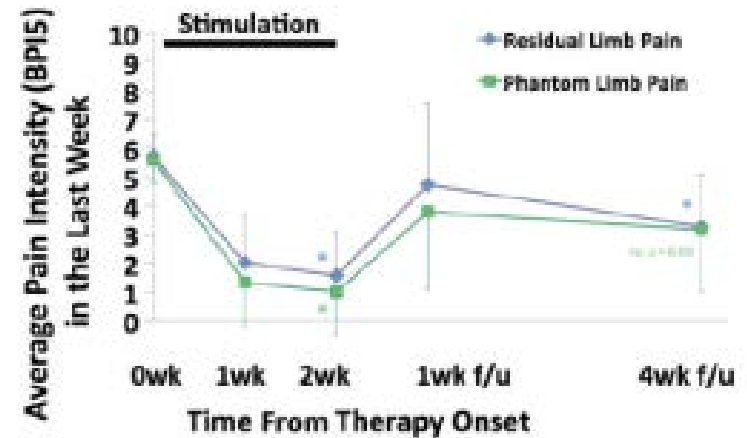
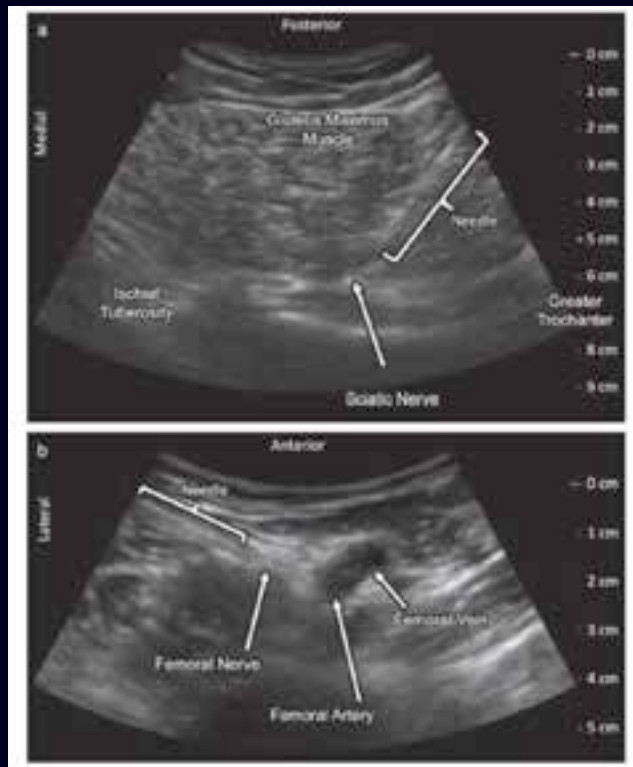
- The lowest activation threshold for the nerve trunk when the electrode and nerves are parallel.
- With double-guarded electrode configuration a larger area would be activated, but this would include a higher degree of concomitant $A\delta$ fiber activation.
- With a single-guarded cathode, the overall threshold is lower, and for most intensities, the relative ratio between $A\beta$ and $A\delta$ fiber activation is increased compared with the double-guarded electrode configuration.

Stimulation Parameters

- The electrical stimulation parameters include a rate of 65– 80 Hz, voltage of 0.8– 1.2V and pulse width between 400 and 500 μ s.
- A guarded electrode combination - + - or dual-guarded - + + - tends to provide the best results; however when **lead is placed adjacent to nerve a monopolar stimulation is sufficient**
- PFNS: voltage ranging from 2.1V to 5.7V, at pulse widths of 350 - 450 μ sec

Peripheral Nerve Targets

Post Amputation Pain

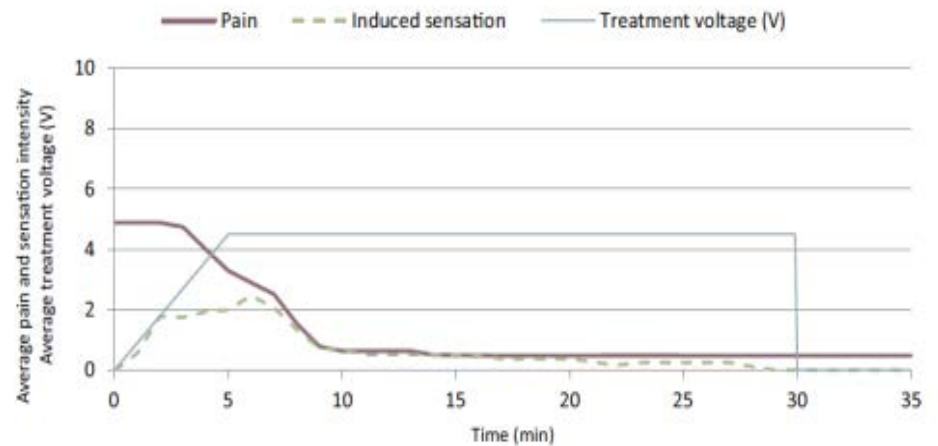
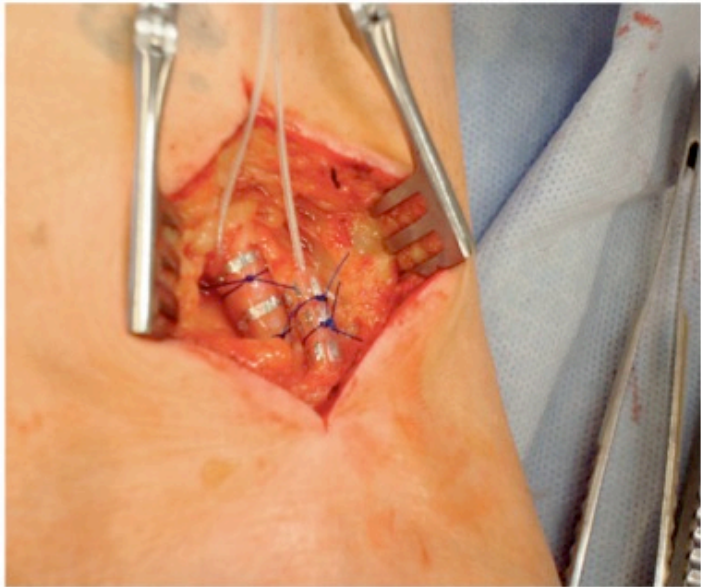


This study suggests:

- PNS single-contact percutaneous lead can be placed quite away from the target nerve
- Significant carryover pain relieving effect was observed

"Extraordinary claims require extraordinary evidence"
Carl Sagan

Surgical cuff lead



Soin A Neuromodulation 2015

High Frequency Blockade

- Pilot study
- N = 7
- 30 minute treatment
 - 67% patients received 9+ hours of relief
- One year follow up
- 5 or 10 kHz
- 5.5 V

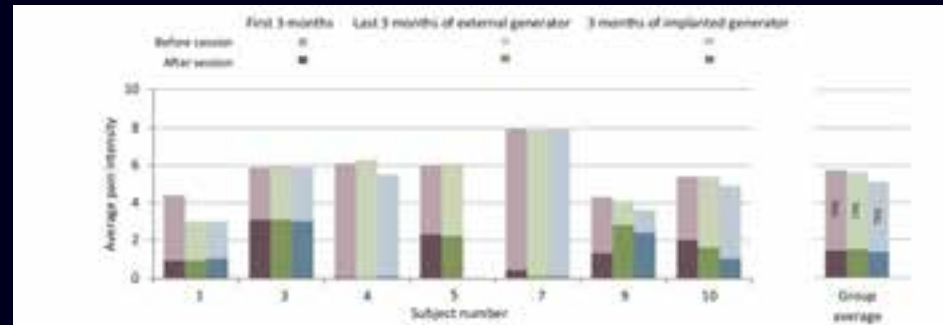


Figure 3. Pain reduction at three-month primary end point and follow-ups.

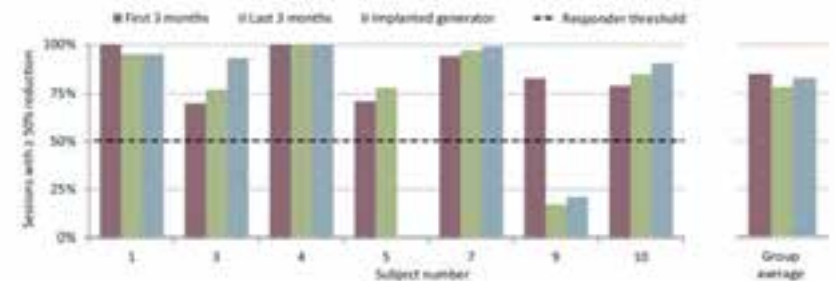


Figure 4. Response rates at three-month primary end point and follow-ups.

Off-Label SCS Equipment for PNS

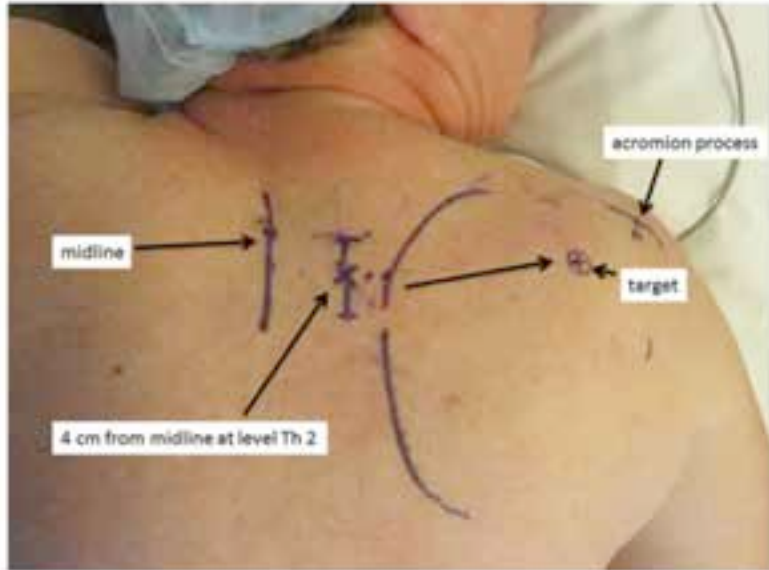


Fig. 1 Positioning of the patient and anatomical landmarks.

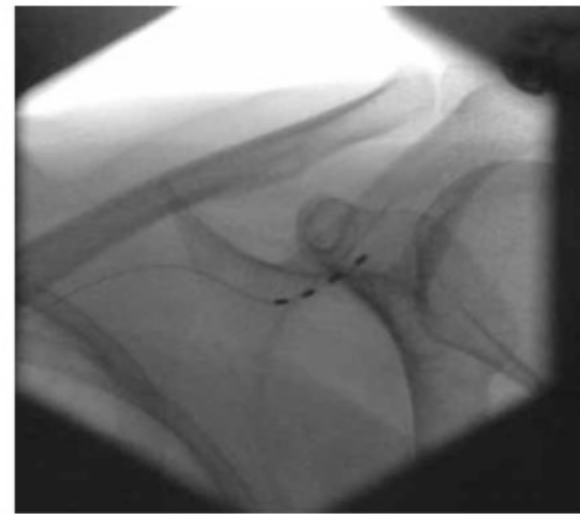


Fig. 2 Intraoperative X-ray showing the position of the lead.

Kurt E Pain Physician 2016

Post-Stroke Shoulder Pain: Key points

- The incidence of post stroke shoulder pain varies from 9% to 73%
- Spasticity and hemiplegic shoulder pain are related



Interventions

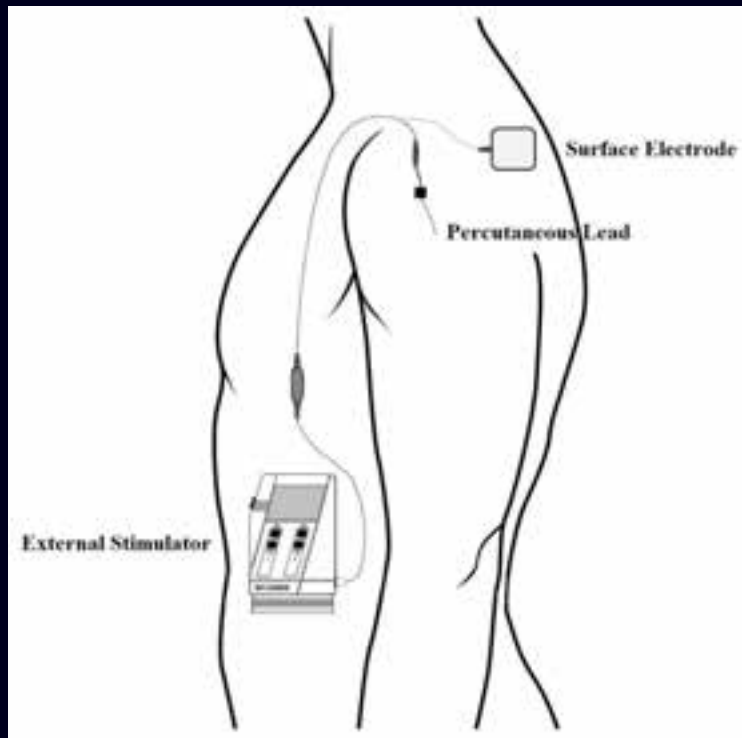
- It is uncertain if strapping helps to prevent or reduce HSP
- There is limited evidence that shoulder slings prevent the development of subluxation
- Aggressive ROM exercises results in a markedly increased incidence of HSP
- Ultrasound treatment is not helpful, NSAIDs may be helpful
- It is unclear whether injections of botulinum toxin reduce pain or improve ROM
- Non-invasive functional electrical stimulation may help to reduce or prevent subluxation, but not pain
- Invasive neuromuscular or peripheral nerve stimulation may help to alleviate pain

Transcutaneous muscular activation

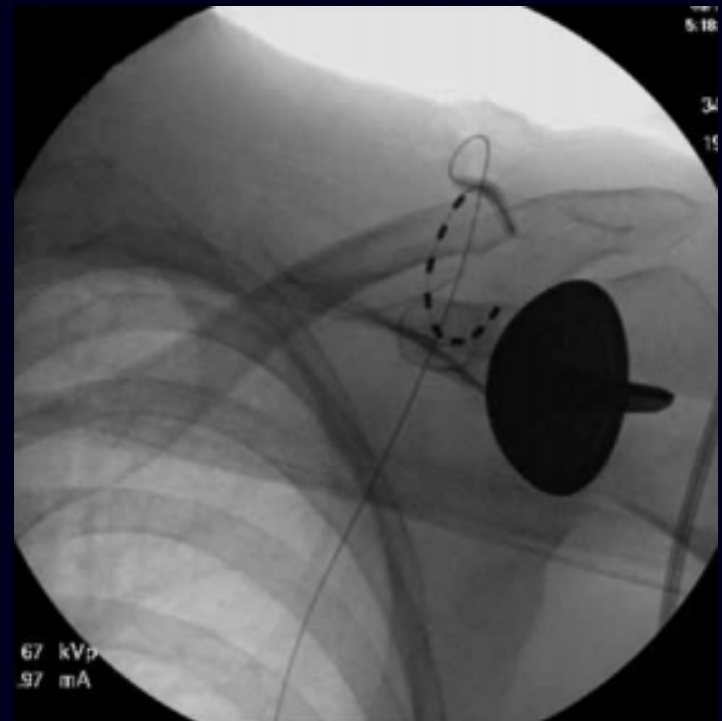


Electrical stimulation

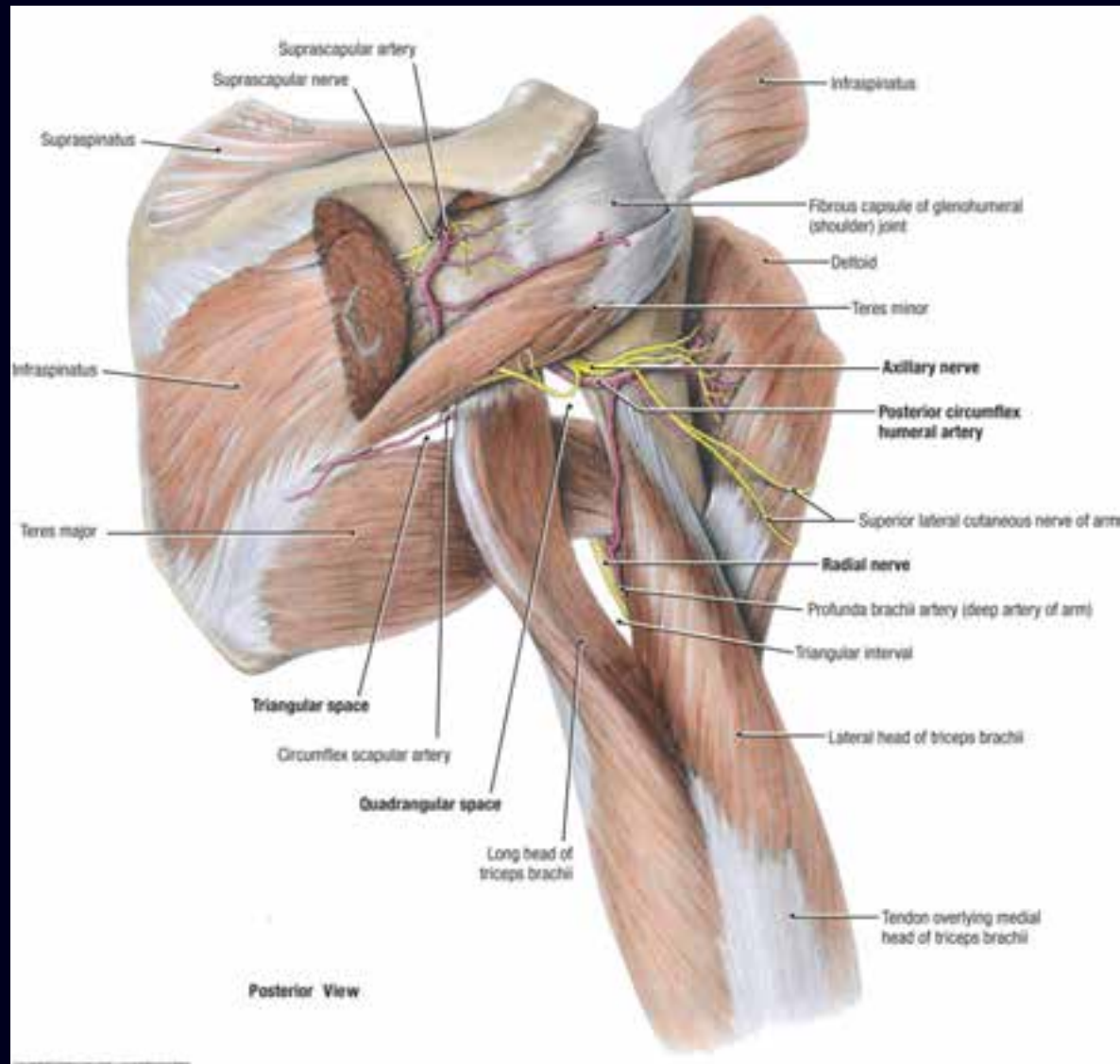
NEUROMUSCULAR



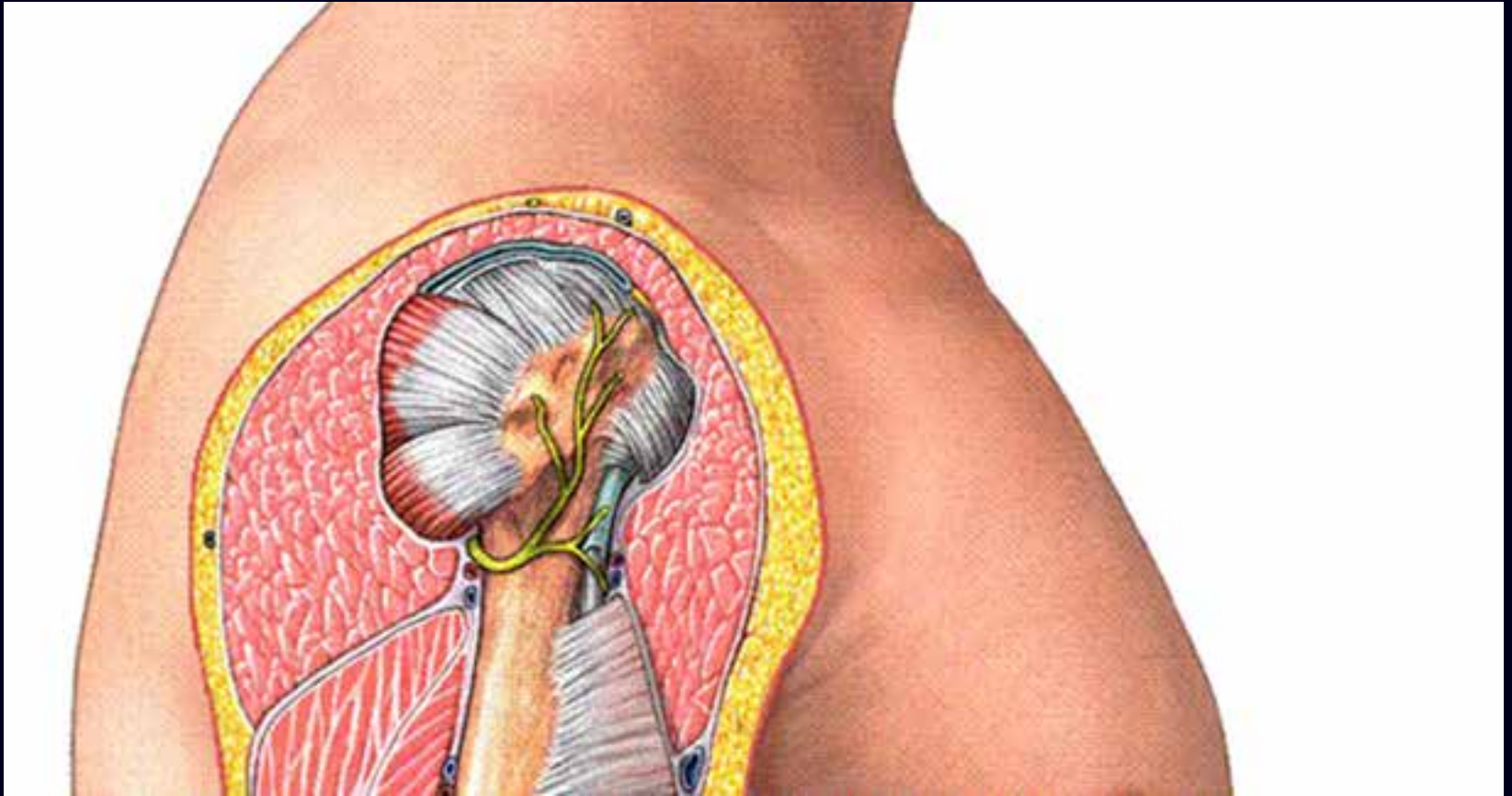
PERIPHERAL NERVE



Shoulder neuroanatomy



Axillary nerve



Sonoanatomy



Intramuscular Neuromuscular Electric Stimulation for Poststroke Shoulder Pain: A Multicenter Randomized Clinical Trial

David T. Yu, MD, John Chae, MD, ME, Maria E. Walker, MSE, Andrew Kirsteins, MD, Elie P. Elovic, MD, Steven R. Flanagan, MD, Richard L. Harvey, MD, Richard D. Zorowitz, MD, Frederick S. Frost, MD, Julie H. Grill, MSE, Michael Feldstein, PhD, Zi-Ping Fang, PhD

Arch Phys Med Rehabil Vol 85, May 2004

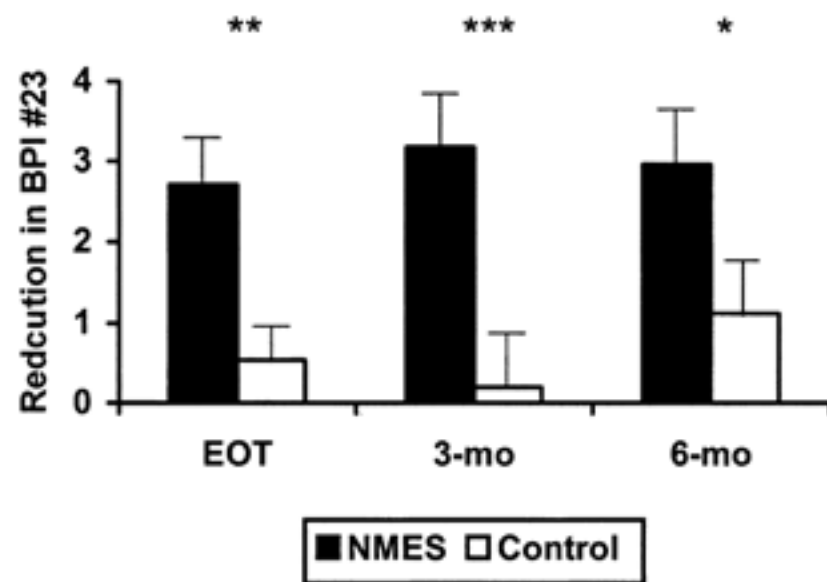
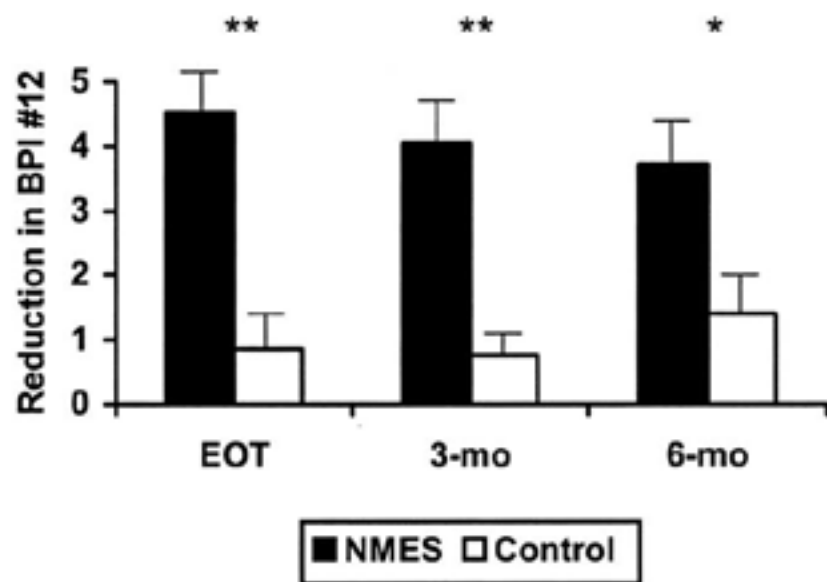
Objective: To assess the effectiveness of intramuscular neuromuscular electric stimulation (NMES) in reducing poststroke shoulder pain.

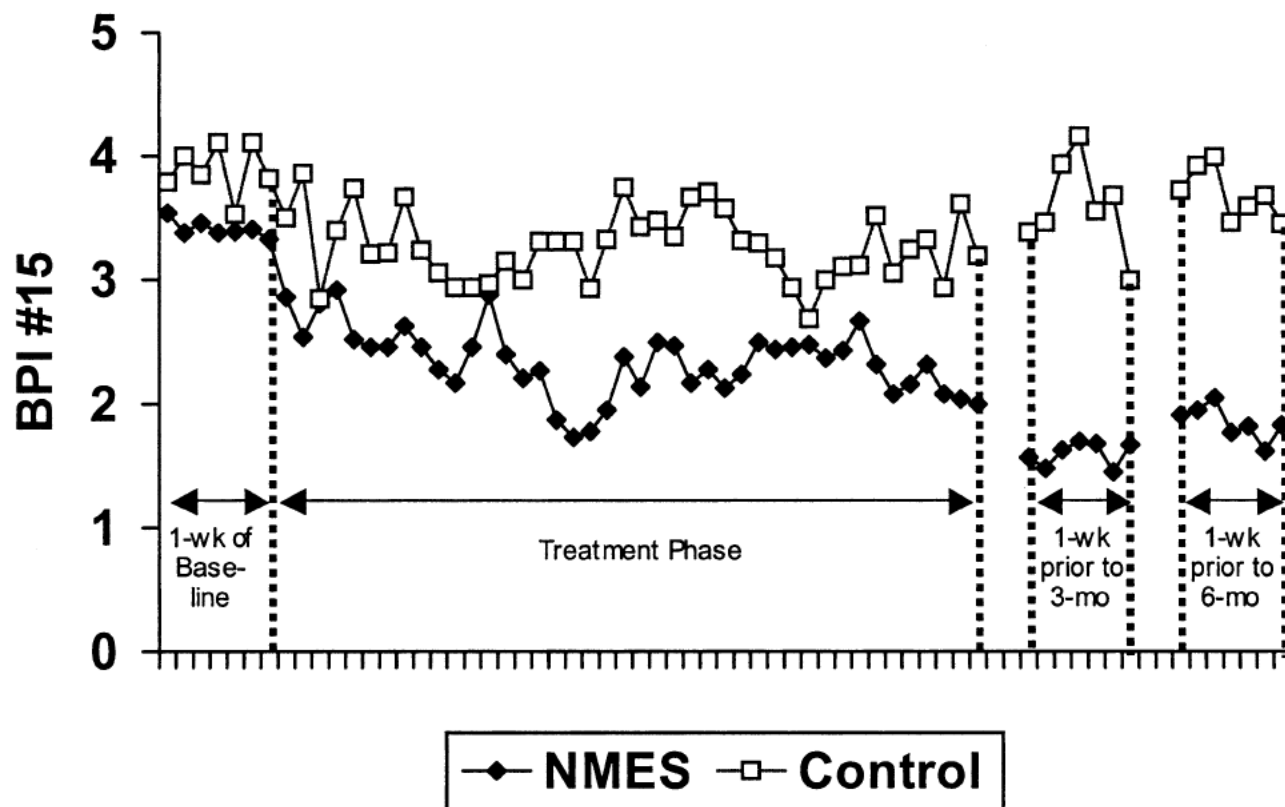
Design: Multicenter, single-blinded, randomized clinical trial.

Participants: Volunteer sample of 61 chronic stroke survivors with shoulder pain and subluxation.

Intervention: Treatment subjects received intramuscular NMES to the supraspinatus, posterior deltoid, middle deltoid, and trapezius for 6 hours a day for 6 weeks. Control subjects were treated with a cuff-type sling for 6 weeks.

Main Outcome Measure: Brief Pain Inventory BPI-12





ORIGINAL RESEARCH ARTICLE

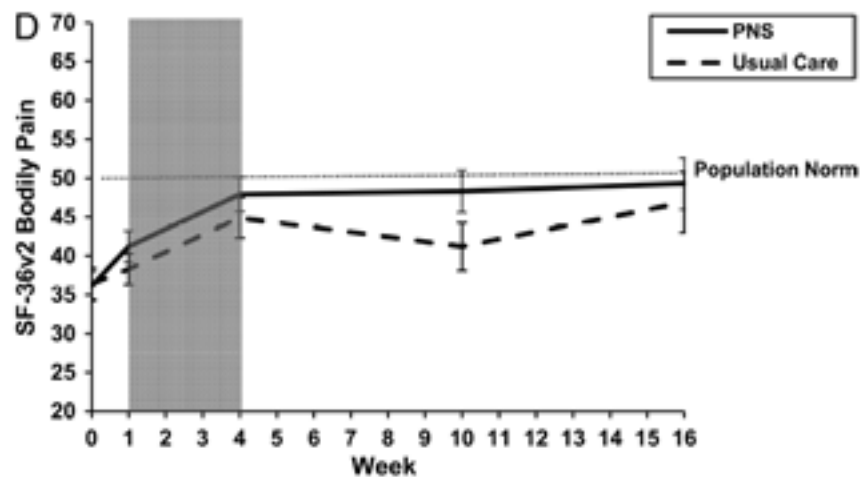
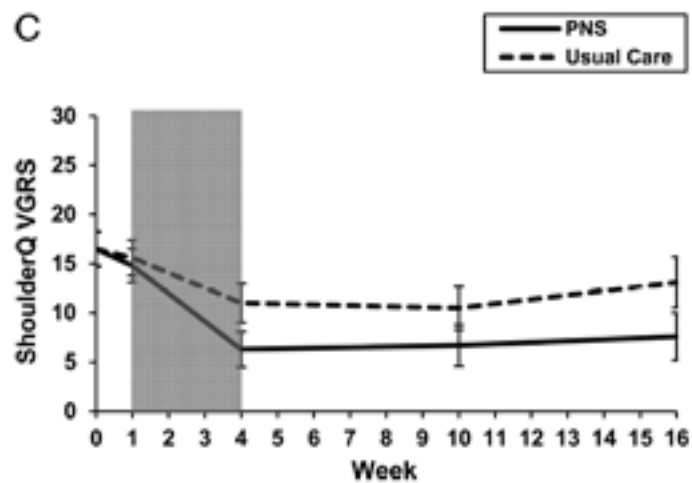
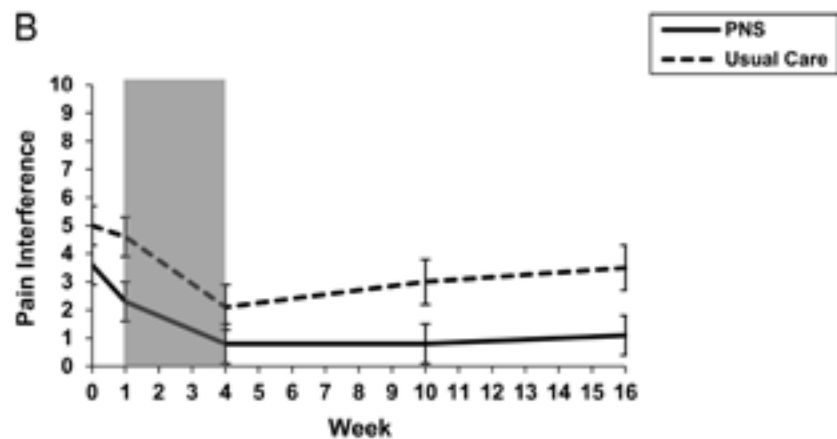
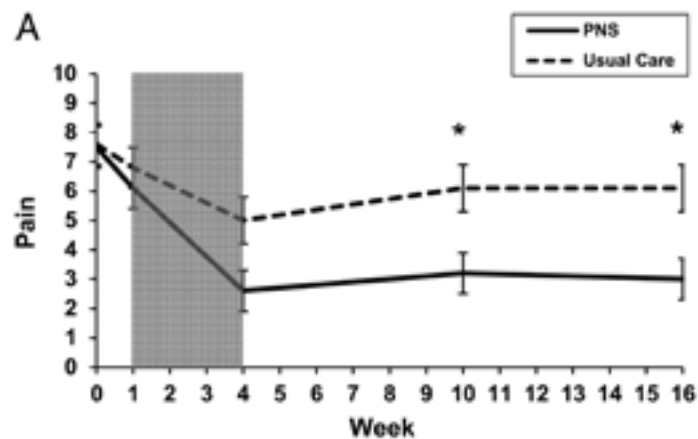
Peripheral Nerve Stimulation Compared with Usual Care for Pain Relief of Hemiplegic Shoulder Pain

A Randomized Controlled Trial

Richard D. Wilson, MD Douglas D. Gunzler, PhD

Maria E. Bennett, MS John Chae, MD.

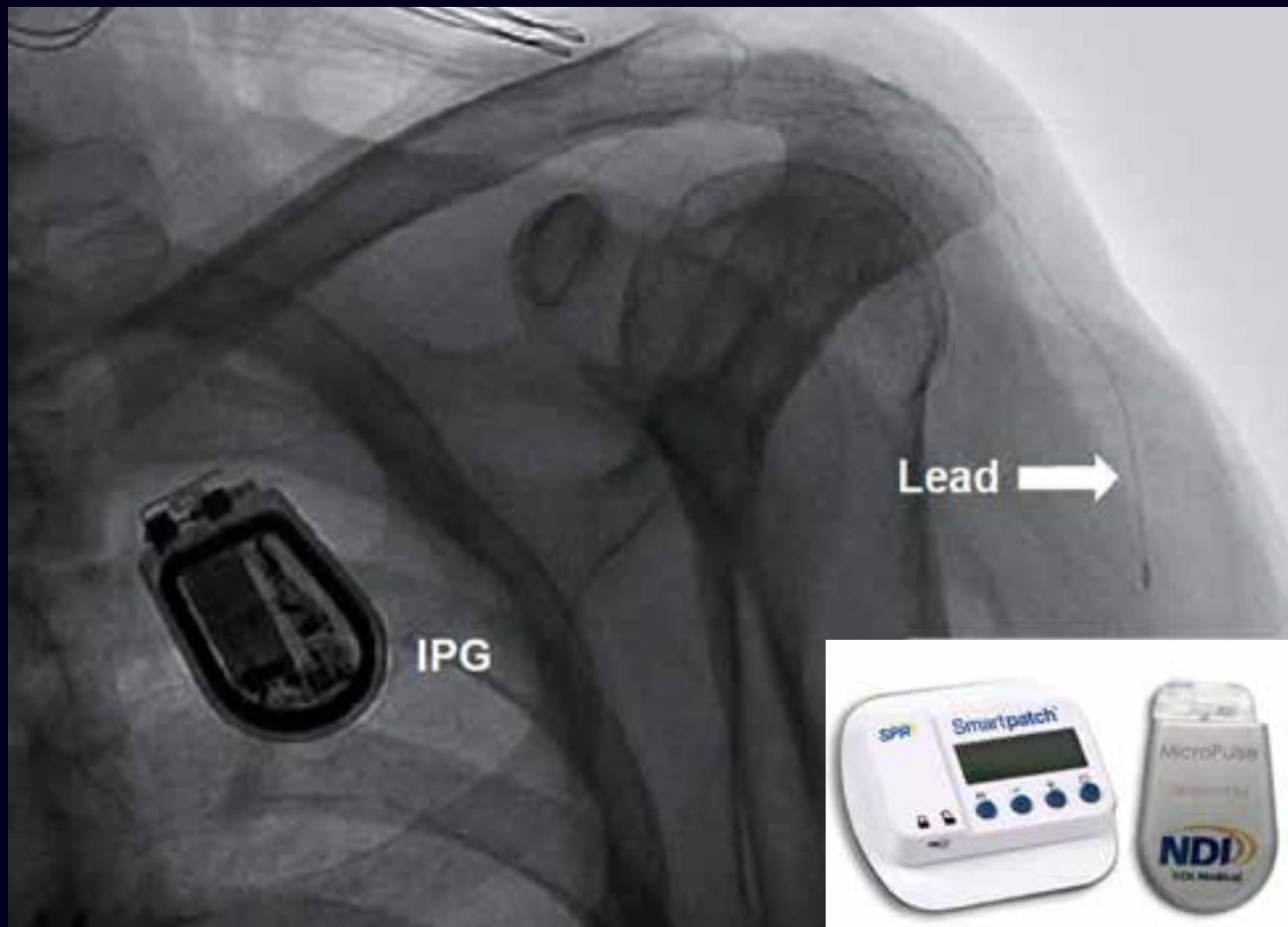
Am. J. Phys. Med. Rehabil. & Vol. 93, No. 1, January 2014



Mechanism of action

- Although PNS was initially designed to improve shoulder subluxation in those with HSP, it has since been found to improve pain despite lack of effect on subluxation or measures of biomechanics
- Electric stimulation of a peripheral nerve decreases intracortical inhibition and has been implicated in cortical reorganization. This mechanism may be responsible for the reported improvements in motor function among some stroke survivors treated with electric stimulation
- Perhaps stimulation of the axillary nerve results in the antidromic activation of C5-C6 spinal DRG and substitution of interrupted spino-cortical transmission and modulation.

IPG + lead (neuromuscular stimulation)



Wireless stimulation



W. Porter McRoberts [poster presentation NANS 2014]

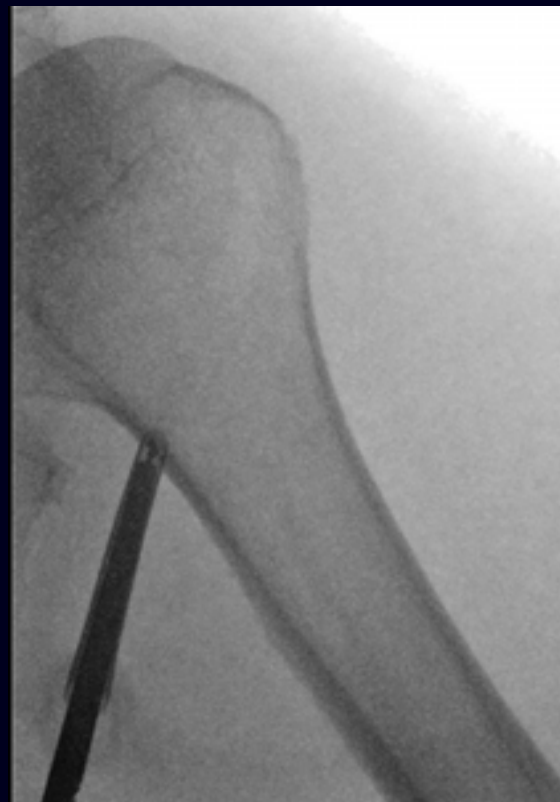
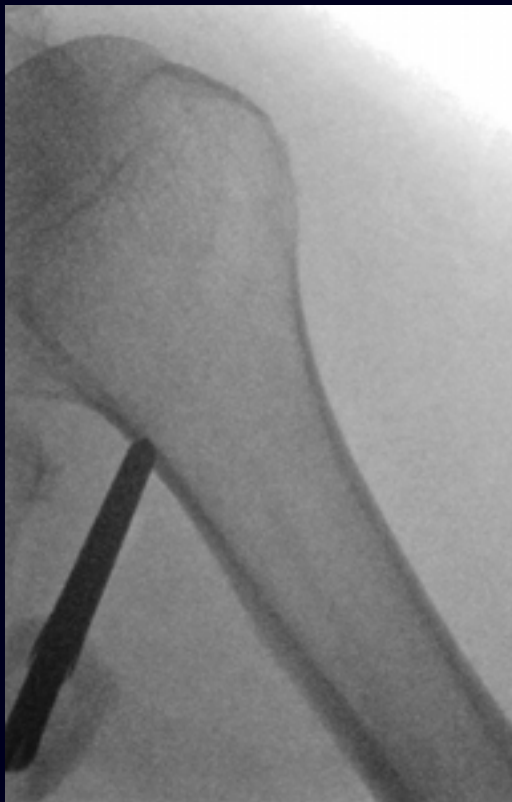
- Since March 2016 23 implantations were performed. Only 2 patients did not obtain pain relief
- A prospective study with historic control in preparation

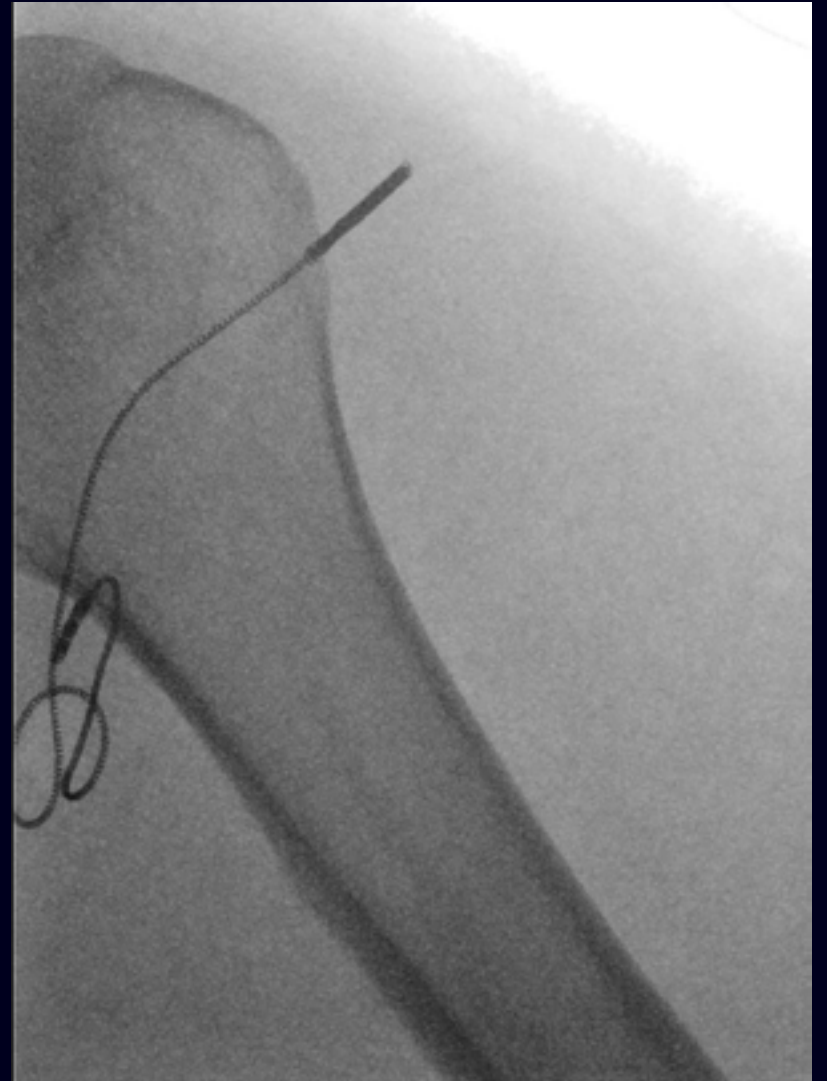
How to perform proper implantation of StimRouter?

- Selection of candidates: > 3 months HSP, w or w/o subluxation, cognitively preserved
- Imaging method: ultrasound is likely best option (accuracy and safety); fluoroscopy + stimulation – alternative selection
- Positioning: prone (fluoro) or lateral decubitus (ultrasound)
- Insertion: coaxial view (fluoro) or lateral to medial aiming to the main trunk of the axillary nerve (ultrasound)
- External patch: lateral deltoid

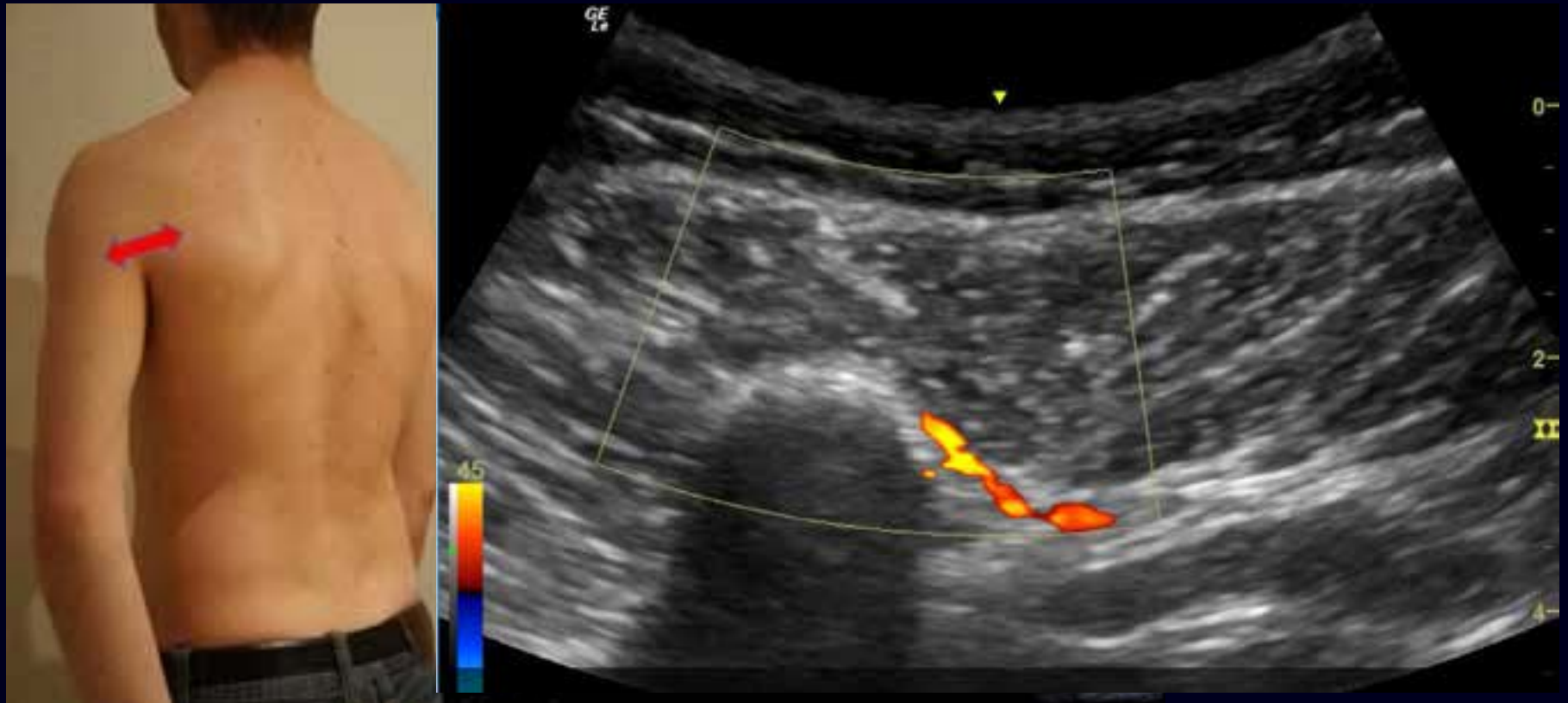
Fluoroscopy-guided approach



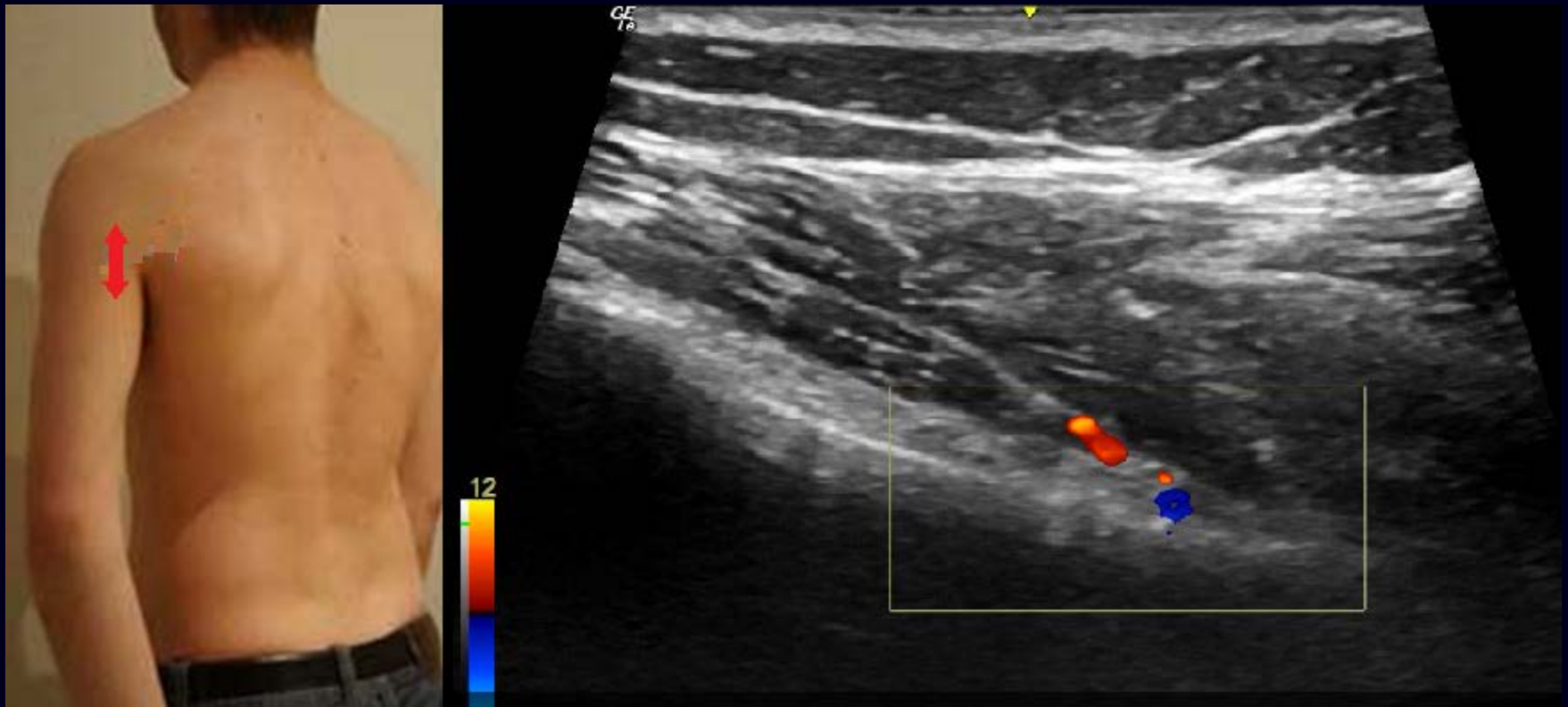


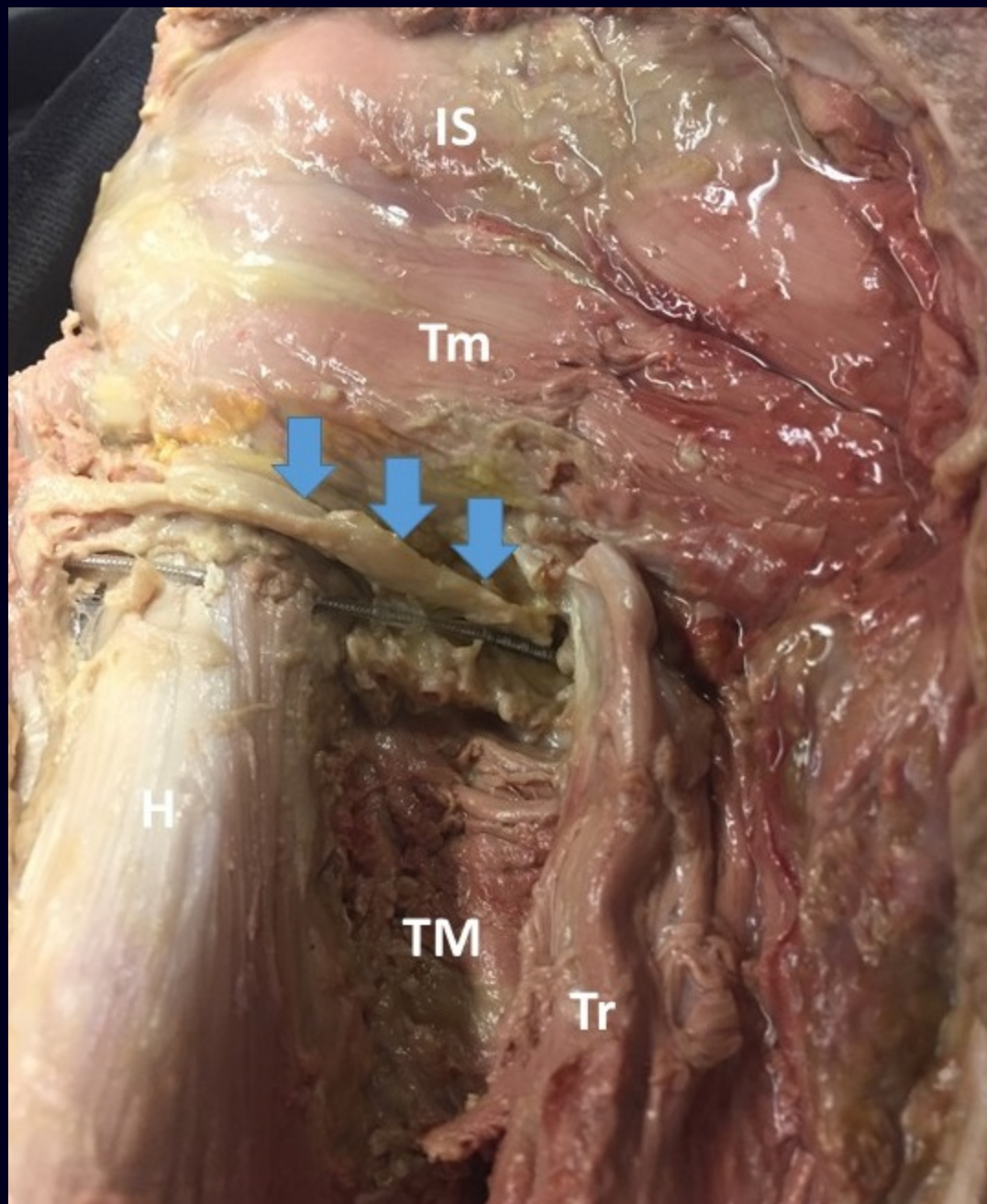


POSTERIOR CIRCUMFLEX ARTERY AND QAS



Posterior circumflex artery and AN





Other Nerve Targets

- Upper extremity: suprascapular, median, ulnar, radial
- Lower extremity: sciatic, tibial, fibular, saphenous, LFCN
- Trunk: intercostal, ilioinguinal/iliohypogastric, genitofemoral
- Pelvis: pudendal

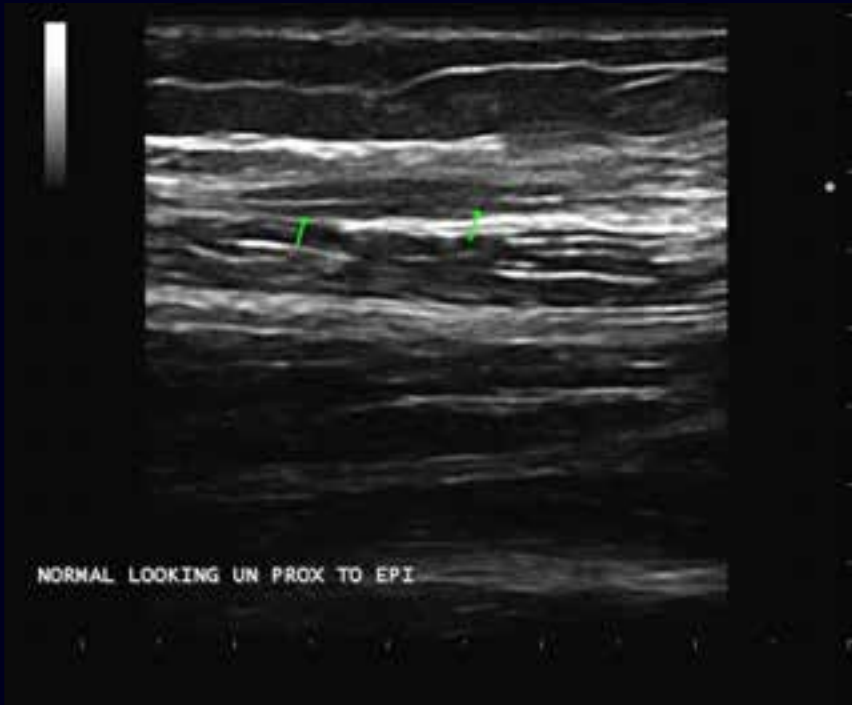
Not FDA-approved for craniofacial pain

General Principles

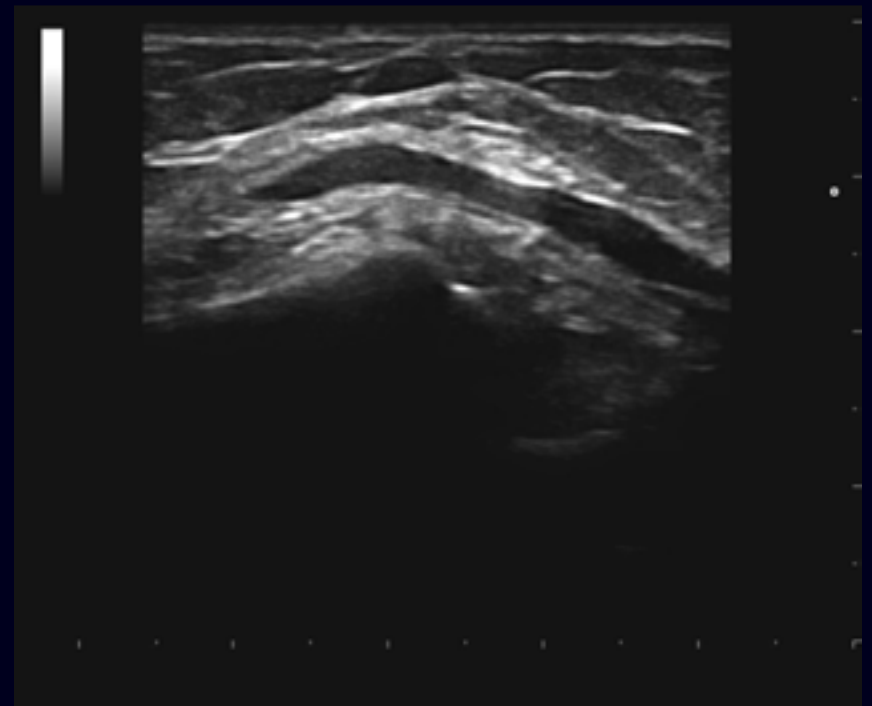
- Carefully plan final active lead position (e.g. do not place the lead under the retinaculum)
- Carefully plan final position of the receiver (e.g. avoid allodynic area)
- Use color Doppler
- Avoid the lead placement at the injured segment
- Generally, an out-of-plane method is preferred because:
 - a. nerves easier to find in their short-axis
 - b. intraoperative testing is more feasible
- Have sufficient distance between the target and needle entry point to assure parallel placement (e.g. a superficial nerve ~ 2 inches)

Ulnar Neuropathy

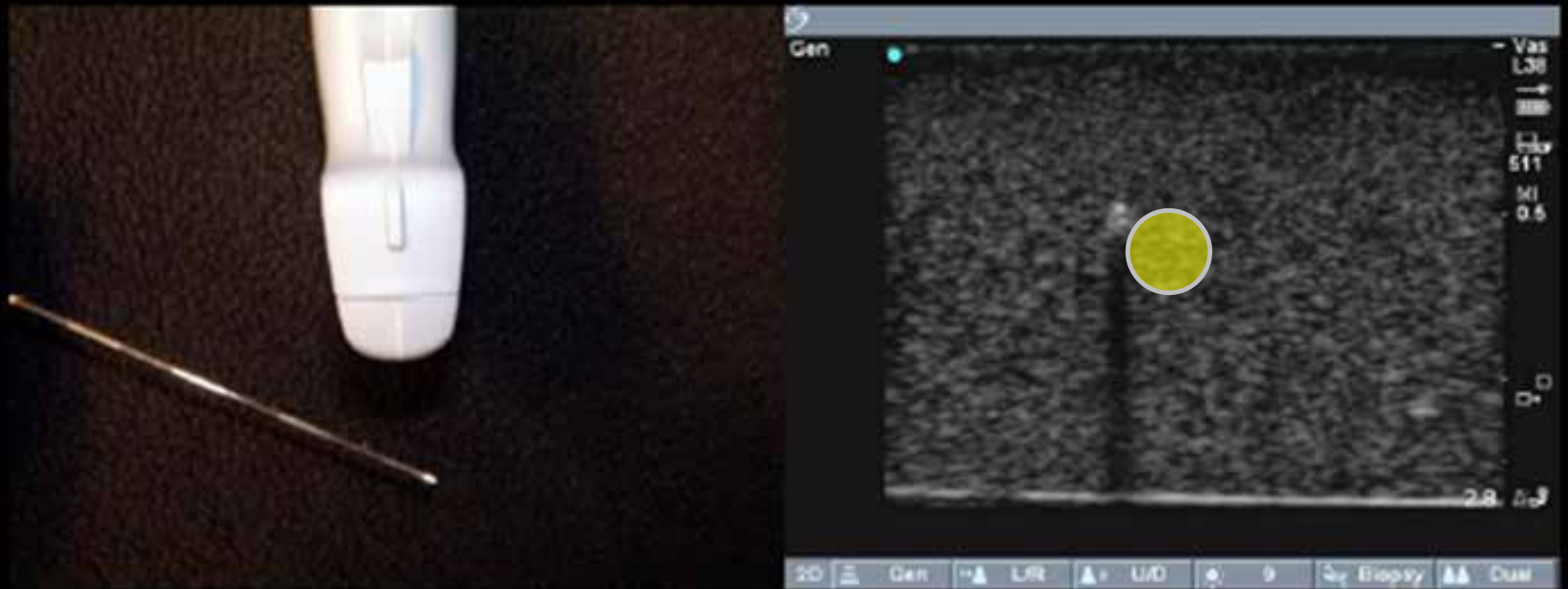
Normal

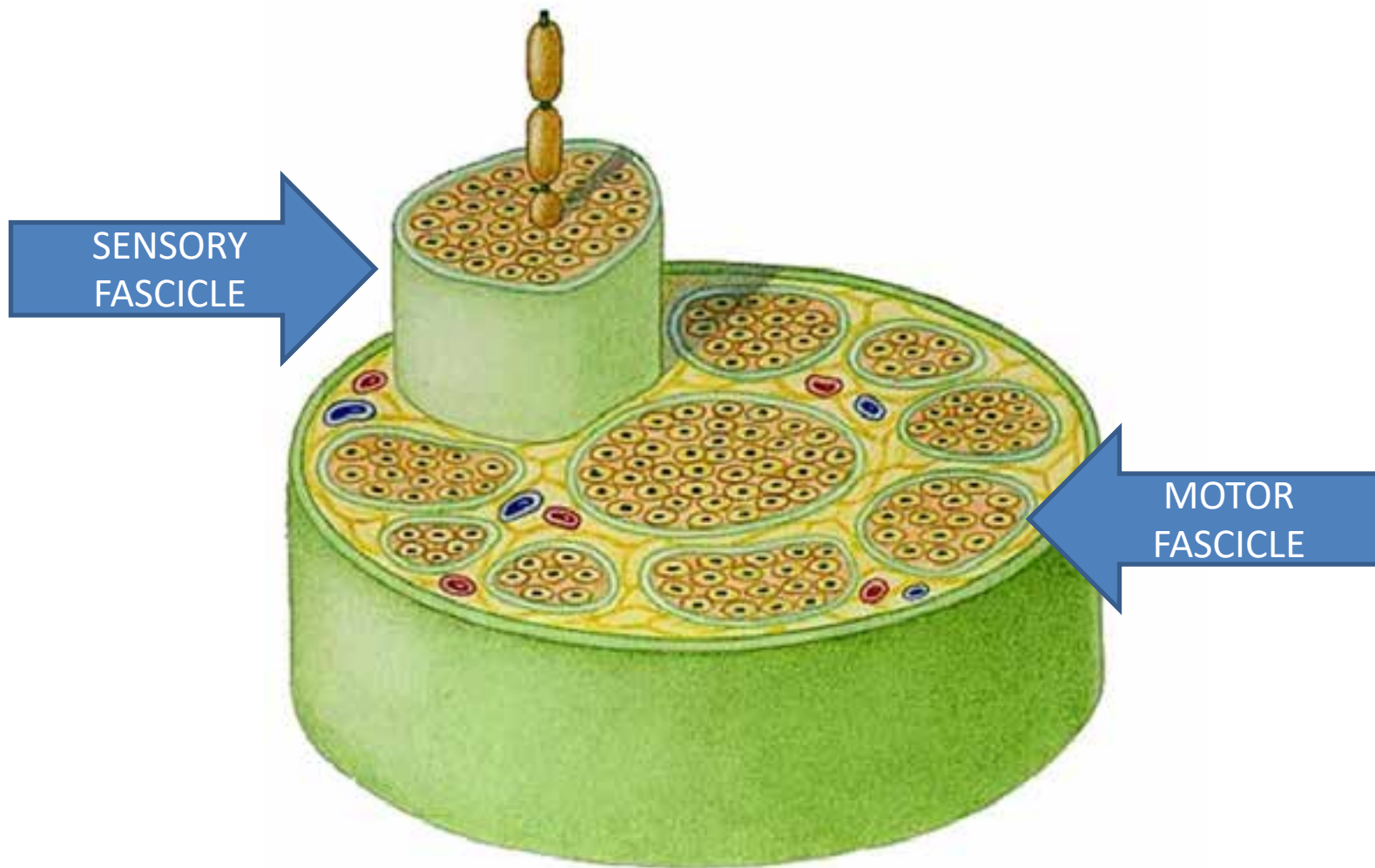


Swollen Hypoechoic Nerve

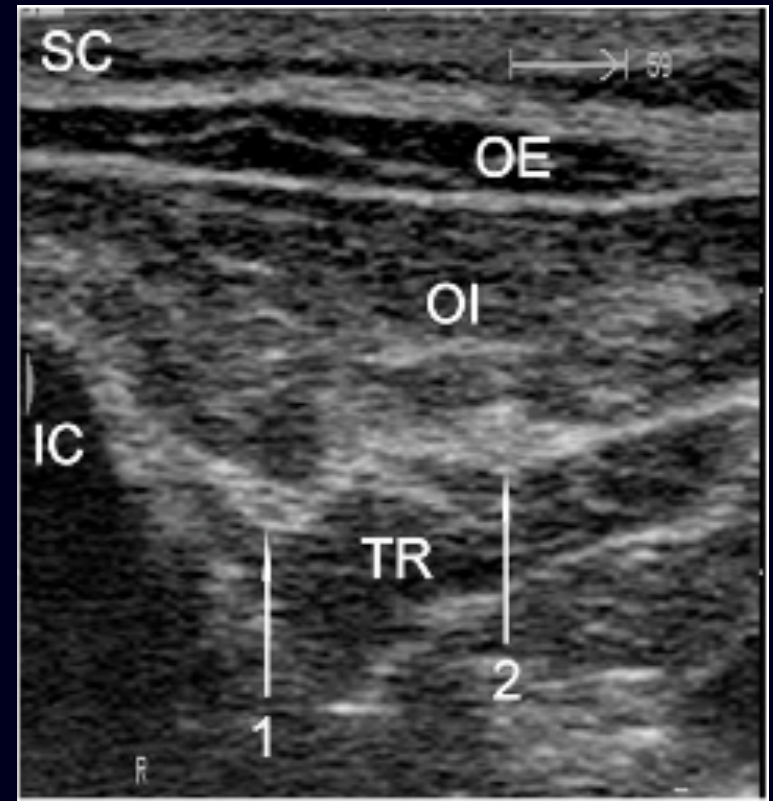
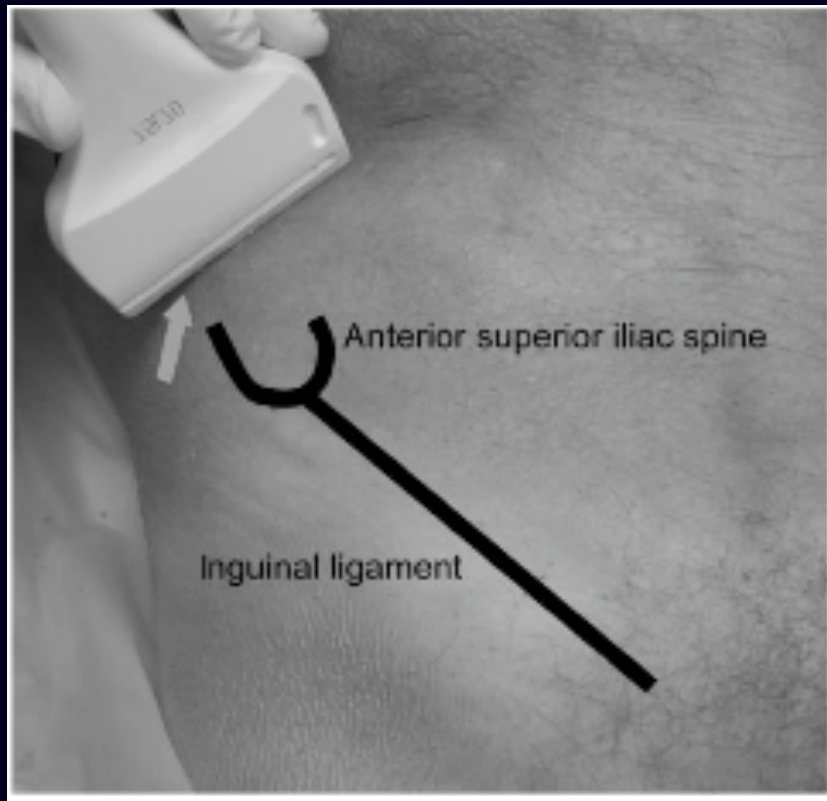


Tracking Needle Movement **OUT OF PLANE APPROACH**



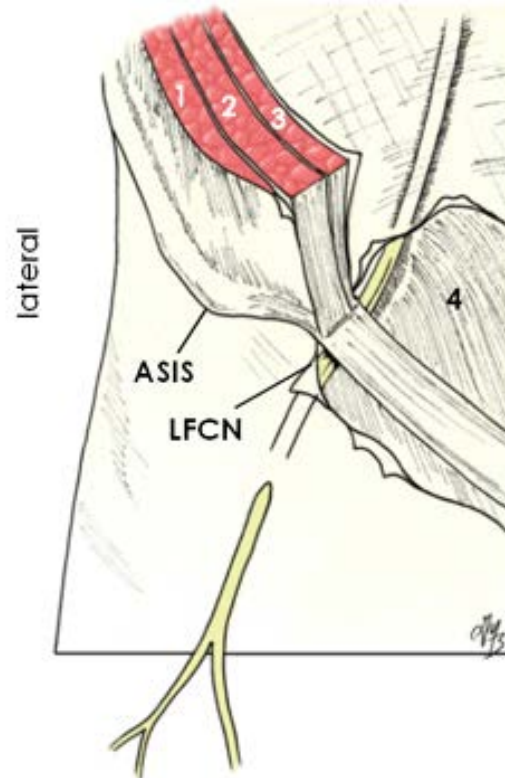
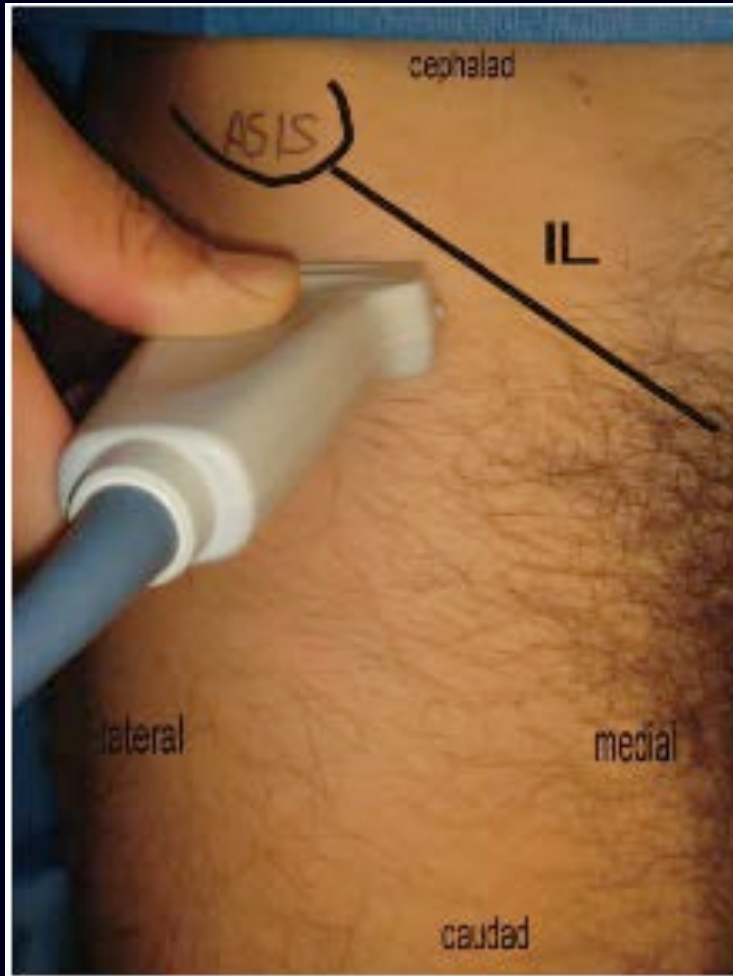


Ilioinguinal/Iliohypogastric Nerve



Eichenberger U, et al. Ultrasound-guided blocks of the ilioinguinal and iliohypogastric nerve: accuracy of a selective new technique confirmed by anatomical dissection. BJA 2006;97:238–43.

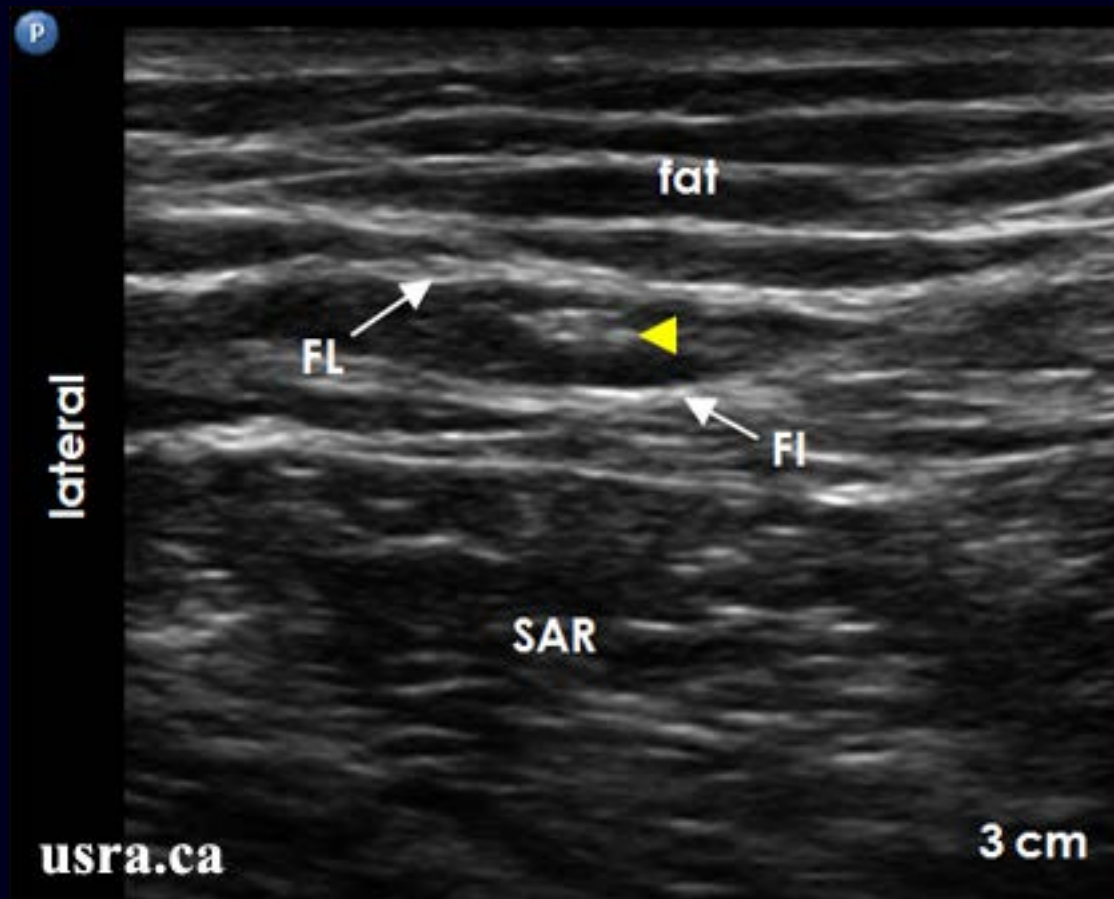
Lateral Femoral Cutaneous Nerve



- 1 = external oblique muscle
- 2 = internal oblique muscle
- 3 = transverse abdominis muscle
- 4 = iliacus muscle
- ASIS = anterior superior iliac spine
- LFCN = lateral femoral cutaneous nerve

Ng I et al. Ultrasound imaging accurately identifies the lateral femoral cutaneous nerve. Anesth Analg 2008;107:1070-4

Lateral Femoral Cutaneous Nerve



Questions?

THANK YOU