Advanced Neuroanatomic Understanding of The Shoulder and Implications for Pain Management

Maxim S. Eckmann, MD
Professor/Clinical, Department of Anesthesiology
Executive Director of Pain Medicine
University of Texas Health Science Center at San Antonio

Disclosures

- Employment
  - University of Texas Health Science Center at San Antonio
- Research Support
  - Avanos Medical Inc – cadaver donation
- Fellowship Education Grants
  - Abbot
  - Boston Scientific
  - Medtronic
- Speaker Panel / Course Director
  - Dannemiller, Inc.
  - American Society of Regional Anesthesia and Pain Medicine
- Investments
  - Insight Dental Systems
  - iKare MTRC (Behavioral Health)

17th Annual Pain Medicine Meeting

November 15–17, 2018 | San Antonio, TX
J.W. Marriott San Antonio Hill Country Resort

www.asra.com/pain | #ASRAFALL18

Abstract deadline: Sept. 5 | Early-bird registration deadline: Sept. 28

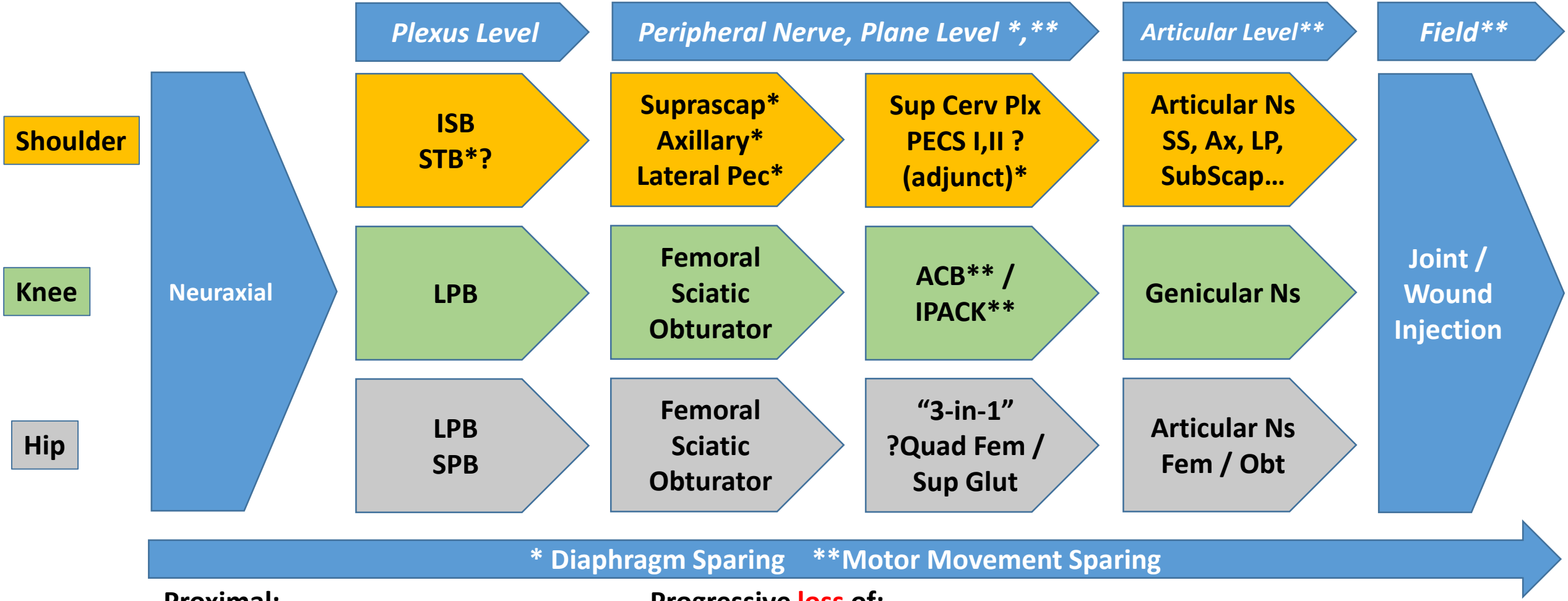
Innovate, Rejuvenate...in the heart of Texas

Leveraging Increasingly Peripheral Nerve Blockade in Acute and Chronic Pain

Gains and Losses

Road Map: Joint Analgesia Progression

ISB (interscalene block); STB (superior trunk block);
LPB (lumbar plexus block); ACB (adductor canal block);
LFCN (lateral femoral cutaneous nerve); IPACK (infiltration between popliteal artery and capsule of knee); PECS (pectoralis block)



Proximal:

- *Dermatome*
- *Myotome/Sclerotome*
- *Osteotome/Capsulotome*
- *Motor Block*

Progressive loss of:

- *Cutaneous, muscular anesthesia.*

Progressive gain of:

- *Motor function*

Distal:

- *Osteotome/Capsulotome*
- *Motor preservation*

Evolving understanding: Shoulder Joint

Selected Developments in Regional Anesthesia for the Upper Extremity and Shoulder

- **Axillary (brachial plexus) block**

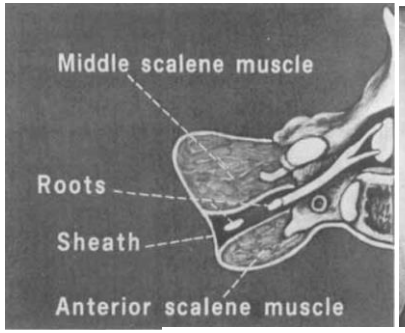
Burnham, P. J.: Regional Block of the Great Nerves of the Upper Arm. Anesthesiology 19:281-284 (March-April) 1958.

REGIONAL BLOCK OF THE GREAT NERVES OF THE UPPER ARM

Dr. Preston J. Burnham of Salt Lake City, Utah, observed complete denervation of the arm in an 11-year old boy from a laceration at the apex of the axilla and was impressed with the potential efficacy of a block at this level.

- **Interscalene Block**

Winnie AP: Interscalene brachial plexus block. Anesth Analg Curr Res 49:455–466, 1970



a simple, safe technic for extending the usefulness of perivascular anesthesia to include surgery and/or manipulations of the upper arm, shoulder, and even neck without the need to use inordinately large volumes.

- **Complications**

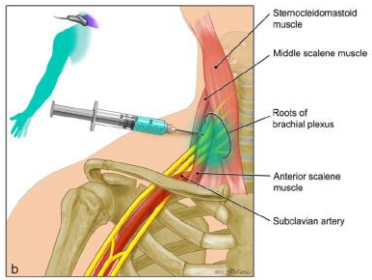
Anesthesiology
V 35, No 6, Dec 1971

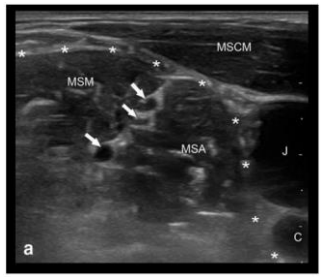
Bilateral Cervical and Thoracic Epidural Blockade Complicating Interscalene Brachial Plexus Block: Report of Two Cases

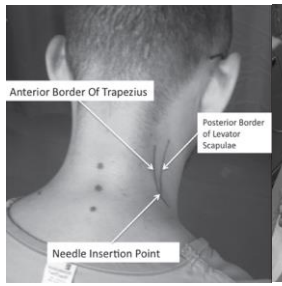
ANIL KUMAR, M.B., B.S.,* GEORGE E. BATTIT, M.D.,†
ALISON B. FROESE, M.D.,‡ MICHAEL C. LONG, M.D.‡

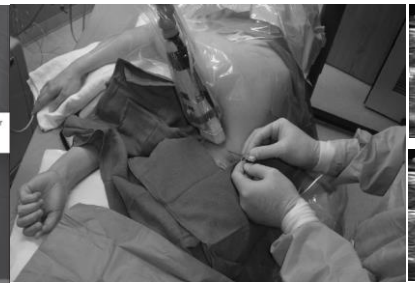
Interscalene Block Development and Complications

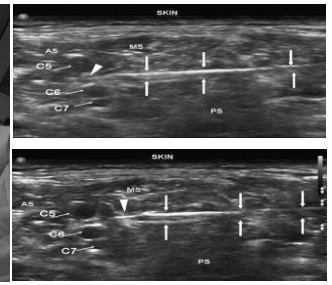
- Multiple Approaches (e.g. Anterolateral, Posterior, etc.)

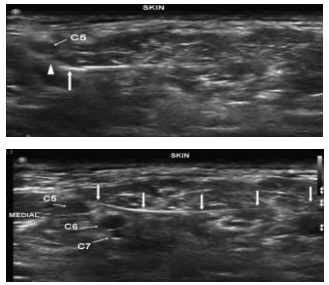












- Single Injection and Continuous Techniques
- Image Guidance
- Noted Unlikely (<1%) but Serious Complications:
  - Neuraxial Injection
  - Persistent Phrenic Nerve Palsy
  - Transient or Prolonged Dysphonia
  - Pneumothorax
  - Dorsal Scapular Nerve Injury
  - Median or Ulnar Neuropathy
  - Plexopathy
  - Complex Regional Pain Syndrome
  - Neuralgias
  - Long Thoracic Nerve Injury

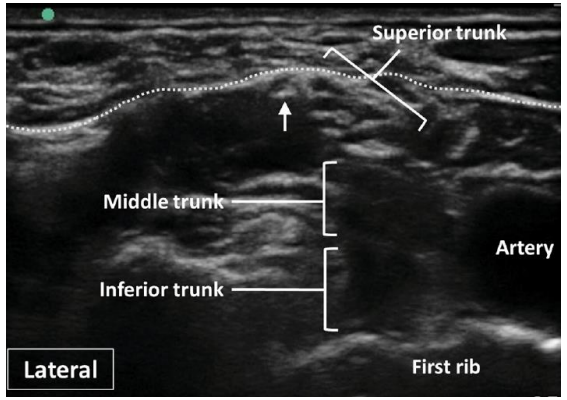
1. McNaught A, et al. Pain Res Manag. 2010 Jul-Aug;15(4):219-23.
2. Nadeau MJ, et al. Can J Anaesth. 2013 Mar;60(3):304-20.
3. Mian A, et al. Clin Anat. 2014 Antonakakis JG, et al. Reg Anesth
4. Borgeat A, et. al. Anesthesiology. 2001 Oct;95(4):875-80.
5. Villar T, et. al. Injury. 2015 Jul;46(7):1409-10.

Motor Sparing Blocks: Diaphragm

- **Superior Trunk Approach**

Burckett-St Laurent D, Chan V, Chin KJ. Can J Anaesth. 2014 Dec;61(12):1098-102.

Lin JA, Chuang TY, Yao HY, Yang SF, Tai YT. Br J Anaesth. 2015 Dec;115(6):932-4.

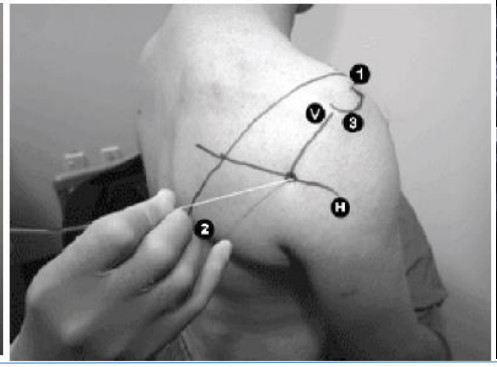


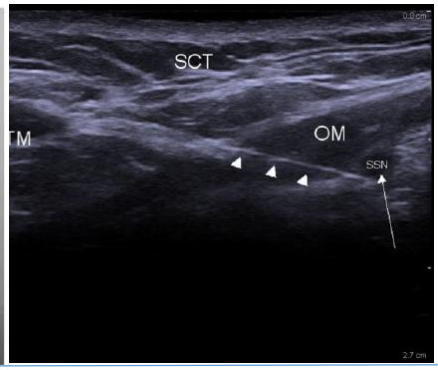
This technique, although effective at providing regional anesthesia of the shoulder, is associated with risks of phrenic nerve palsy, injury to the dorsal scapular and long thoracic nerves, and long-term postoperative neurologic symptoms. In this case report, we describe the ultrasound-guided superior trunk block. This procedure targets the C5 and C6 components of the brachial plexus more distally after they unite into the superior trunk but before the suprascapular nerve branches off.

- **Suprascapular, Axillary N Blocks**

Rothe C, Steen-Hansen C, Lund J, Jenstrup MT, Lange KH. Acta Anaesthesiol Scand. 2014 Nov;58(10):1228-32.

Bowens C Jr, Sripada R. Anesthesiol Res Pract. 2012;2012:971963.





- **Diaphragm Sparing N. Blocks for Shoulder Surgery**

REF: Suprascapular, Axillary, Lateral Pectoral, Subscapular, Supraclavicular Nerves

Tran DQ, Elgueta MF, Aliste J, Finlayson RJ. Reg Anesth Pain Med. 2017 Jan/Feb;42(1):32-38.

Bansal V, Shastri U, Canlas C, Gadsden JC. Reg Anesth Pain Med. 2017 Jul/Aug;42(4):544-545.

Anatomy - New Answers  New Questions

How Many Nerves Supply the Shoulder?

Darcy Price, FANZCA
Department of Anesthesia
North Shore Hospital
Auckland, New Zealand

Regional Anesthesia and Pain Medicine • Volume 43, Number 3, April 2018

- "Their description…demonstrates why blocking the AN [Axillary Nerve] and the SN [Suprascapular Nerve] provides superior postoperative analgesia than blocking the SN alone.
- "However, the minor nerves are not anesthetized, particularly those covering more anterior structures…"
- Dr. Price goes on to describe commonly residual anterior shoulder pain after arthroscopy that lasts 1-2 hours.

Anatomy - New Answers New Questions

How Many Nerves Supply the Shoulder?

Darcy Price, FANZCA
Department of Anesthesia
North Shore Hospital
Auckland, New Zealand

Regional Anesthesia and Pain Medicine • Volume 43, Number 3, April 2018

Reply to Dr Price

Maxim S. Eckmann, MD
Department of Anesthesiology
The University of Texas Health Science Center at San Antonio
San Antonio, TX

Regional Anesthesia and Pain Medicine • Volume 43, Number 3, April 2018

- Lateral pectoral nerve[1,2,3] could be a contributor
- There are probably sensory pathways of undetermined clinical significance from other nerves such as subscapular and musculocutaneous nerves[4]
- Based on Hilton's Law, at least 15 peripheral nerves or ventral rami could contribute to the shoulder

1. Eckmann MS, Bickelhaupt B, Fehl J, et al. Cadaveric study of the articular branches of the shoulder joint. Reg Anesth Pain Med. 2017; 42:564–570.
2. Aszmann OC, Dellon AL, Birely BT, McFarland EG. Innervation of the human shoulder joint and its implications for surgery. Clin Orthop Relat Res. 1996;330:202–207.
3. Nasu H, Nimura A, Yamaguchi K, Akita K. Distribution of the axillary nerve to the subacromial bursa and the area around the long head of the biceps tendon. Knee Surg Sports Traumatol Arthrosc. 2015;23:2651–2657.
4. Wrete M. The sensory pathways from the shoulder joint. J Neurosurg. 1949;6:351–360.

Hilton's Law Applied to Glenohumeral Joint

TABLE 1. An Example of the Application of Hilton's Law: The Glenohumeral Joint

Nerve (origin)	Muscles moving joint	Cutaneous innervation	Explanation	Articular branch	Explanation
Suprascapular (C5-C6)	Supra and infraspinatus	Yes or axillary	Same nerve or same source	Yes	Same nerve
Lateral pectoral (C5-C6-C7)	Pectoralis major (clavicular head)	Sensory branch (variations) or axillary	Same nerve or same source	Yes	Same nerve
Medial pectoral (C8-T1)	Pectoralis major (sternal head), *chondro-epitochlearis*	Sensory branch of lateral pectoral or axillary	Double innervation or neural communication (ansa pectoralis)	Lateral pectoral branch	Double innervation or neural communication (ansa pectoralis)
Upper subscapular (C5-C6)	Subscapularis	Axillary	Same source	Yes (controversial) or axillary	Same nerve or same source
Lower subscapular (C5-C6)	Subscapularis, teres major	Axillary	Same source	Yes (controversial) or axillary	Same nerve or same source
Thoracodorsal (C5-C6-C7)	Latissimus dorsi, *axillary arch*	Axillary	Same source	Lateral pectoral branch	Same source
Axillary (C5-C6)	Deltoid, teres minor	Yes	Same nerve	Yes	Same nerve
Musculo-cutaneous (C5-C6-C7)	Biceps, coraco-brachialis	Yes	Same nerve	Lateral pectoral branch	Same source
Radial (C5-C6-C7-C8-T1)	Triceps	Yes	Same nerve	Yes or from posterior cord	Same nerve or same source

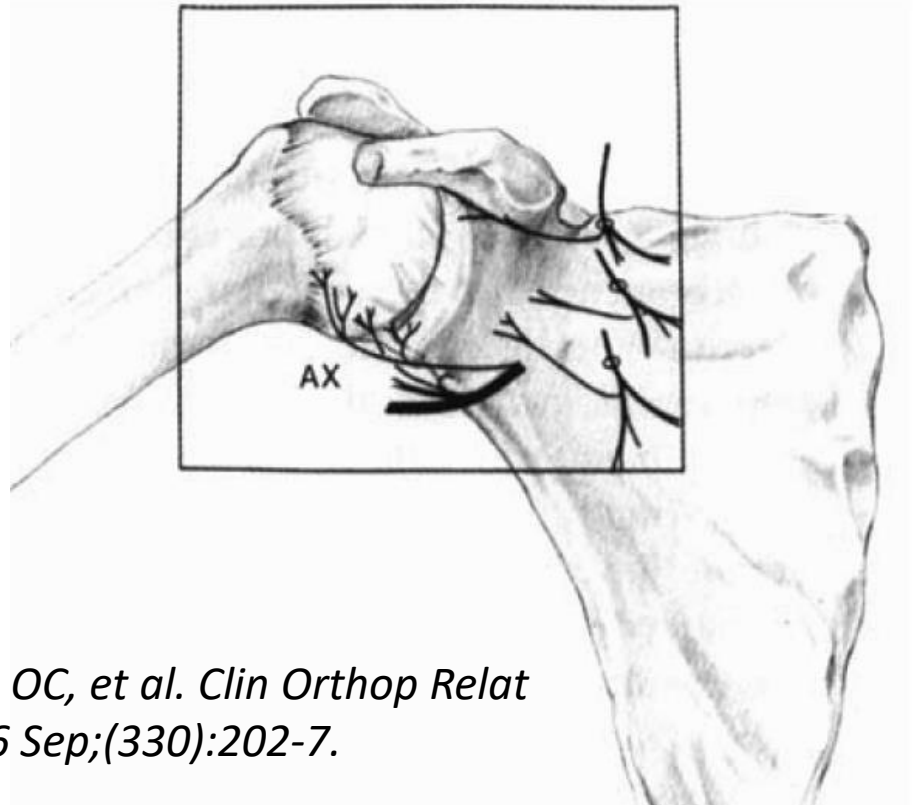
Hébert-Blouin MN, et al. Clin Anat. 2014 May;27(4):548-55.

Suprascapular Nerve			
Author and Year	**Specimens**	**Sample Size**	**Articular branch innervation and pathway**
(6) Aszmann et al, 1995	Fresh-frozen adult cadavers	25 shoulders	After entering suprascapular notch, the suprascapular n. sends lateral articular branches to the coracoclavicular ligaments
			After giving off lateral articular branches to the coracoclavicular ligaments, the nerve then gives articular branches to the coracohumeral ligament, subacromial bursa, and posterior acromioclavicular joint capsule.
			After giving a muscular branch to the suprascapular m., the suprascapular n. gives lateral articular branches to the posterior joint capsule.
(20) Ebraheim et al, 2010	Embalmed adult cadavers	12 shoulders	Articular branches came off the main suprascapular n. after passing through the notch to innervate the acromioclavicular joint and subacromial bursa.
(21) Vorster et al, 2008	Embalmed adult cadavers	31 shoulders	After passing the suprascapular notch, the suprascapular n. gives an articular branch which travels superolaterally around the base of the coracoid process then turns to run inferomedially towards the posterior shoulder capsule.
Axillary Nerve			
(6) Aszmann et al, 1995	Fresh-frozen adult cadavers	25 shoulders	As axillary n. crosses subscapular m., it gives articular branch to inferior-anterior joint capsule
(18) Gelber et al, 2006	Fresh-frozen and embalmed adult cadavers	61 shoulders	As axillary n. passes through quadrangular space, wraps laterally around humeral neck, pierces deltoid, and then articular branches continue to pierce IGHL (13.11%).
			After axillary n. passes through quadrangular space, articular branches arise from branch to teres minor (40.98%) or off main axillary n. trunk (24.59%).
(19) Nasu et al, 2014	Embalmed adult cadavers	20 shoulders	As axillary n. passes through quadrangular space, wraps laterally around humeral neck, pierces deltoid, and then articular branches cotinue medially towards humerus, ascends humerus, pierces fascia, then continues to pierce subacromial bursa on lateral or anterolateral shoulder (60%).
			As axillary n. leaves brachial plexus, articular branch pierces connective tissue of the long head of the biceps tendon (40%) and then pierced cortical bone of humers at intertubercular sulcus (15%)
			As axillary n. passes through quadrangular space, the main trunk gives articular branches to inferior joint capsule (75%), posterior joint capsule from teres minor branch (15%), posterolateral long head of the triceps tendon from teres minor branch (15%).
Lateral Pectoral Nerve			
(11) Akita et al, 2002	Unspecified cadavers	125 shoulders	The lateral pectoral n. gives an articular branch to the shoulder joint after passing over the acromion.
(6) Aszmann et al, 1995	Fresh-frozen adult cadavers	25 shoulders	Lateral pectoral n. sends articular branch to coracoclavicular ligament before piercing clavipectoral fascia.
			Lateral pectoral n. passes between coracoacromial and coracoclavicular ligaments to innervate subacromial bursa and anterior acromioclavicular ligament.
(5) Nam et al, 2016	Unembalmed cadavers	43 shoulders	Lateral pectoral n. gives an articular branch along the superomedial margin of the deltoid muscle, along anterior coracoclavicular ligament then piercing the coracoacromial ligament to enter the shoulder joint (67.4%).

Neurologic Innervation: Articular Branches

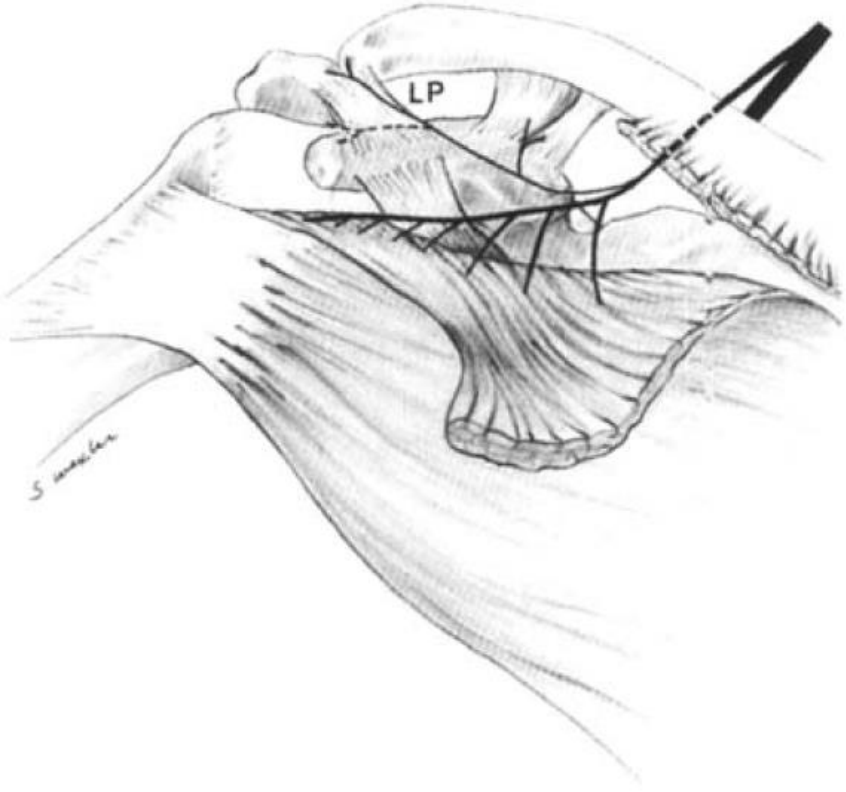
Anterior

- Subscapular Branches
- Axillary Nerve (Anterior Branch)



Aszmann OC, et al. Clin Orthop Relat Res. 1996 Sep;(330):202-7.

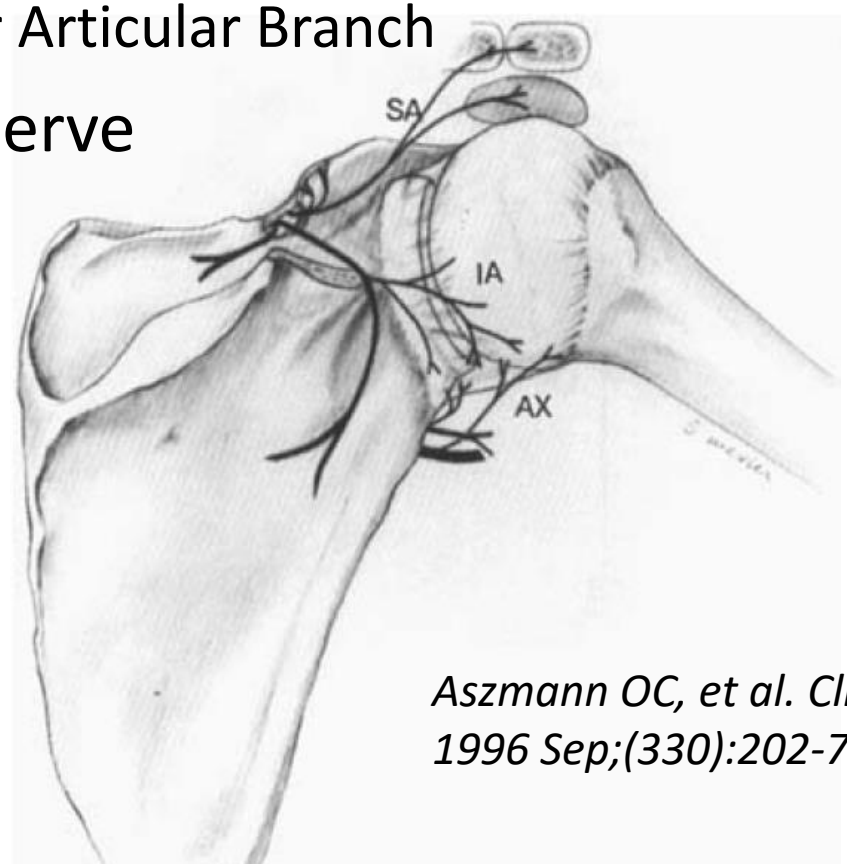
- Lateral Pectoral Nerve (Articular Branch)



Neurologic Innervation: Articular Branches

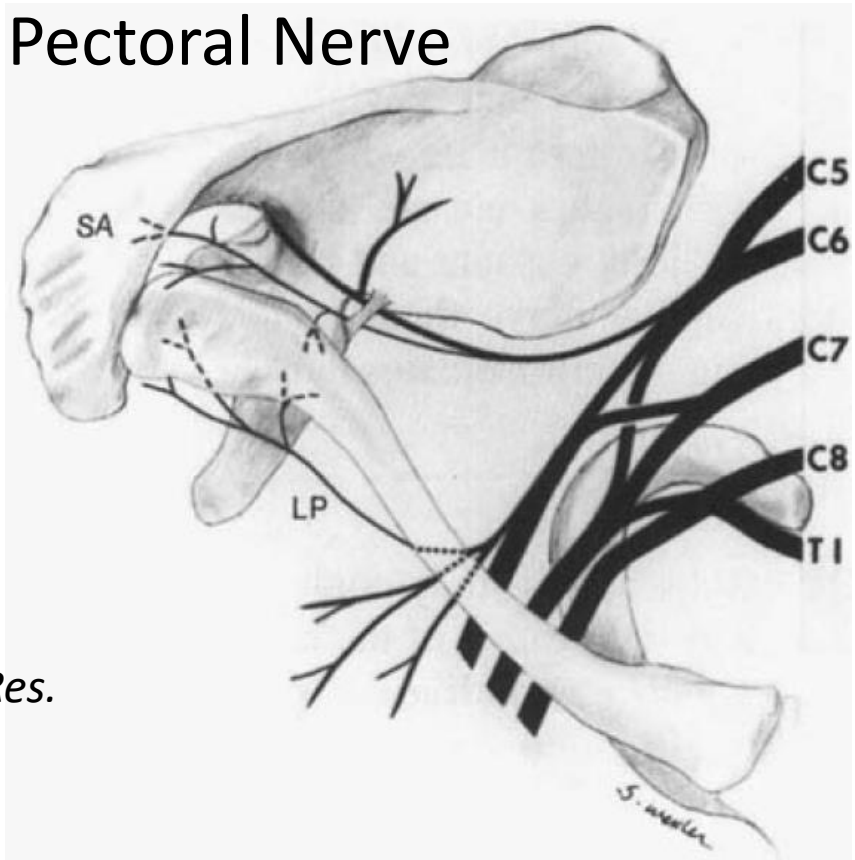
Posterior

- Suprascapular Nerve
  - Superior Articular Branch
  - Inferior Articular Branch
- Axillary Nerve



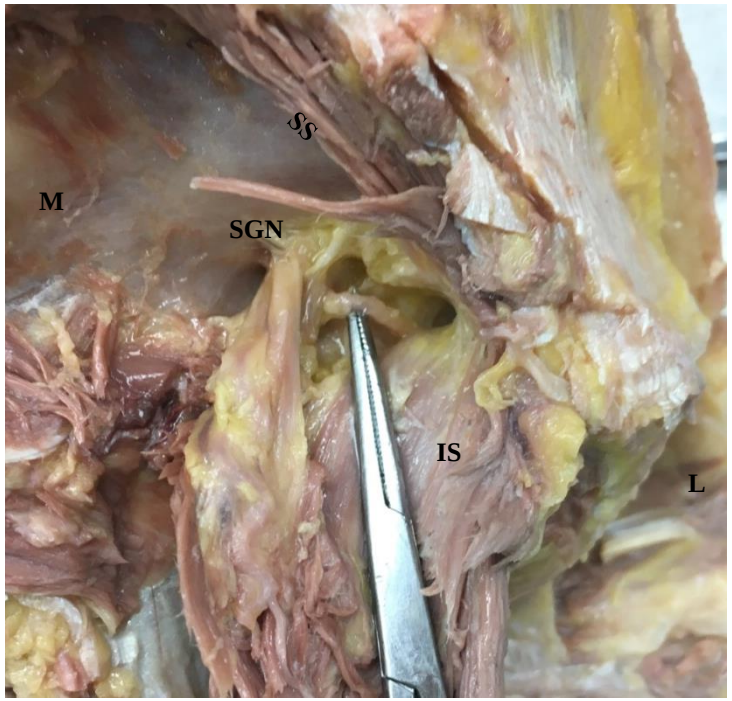
Superior

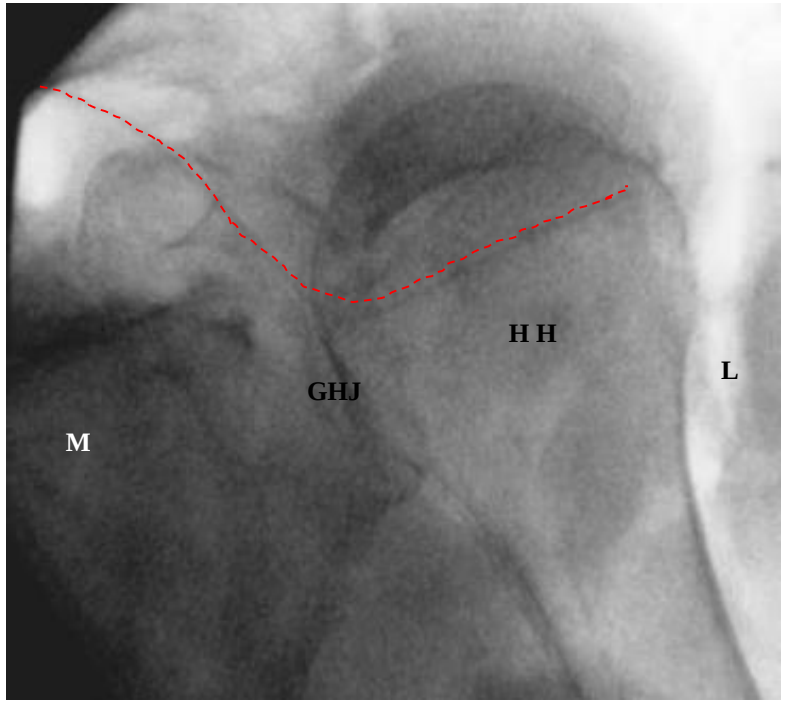
- Suprascapular Nerve
  - Superior Articular Branch
- Lateral Pectoral Nerve

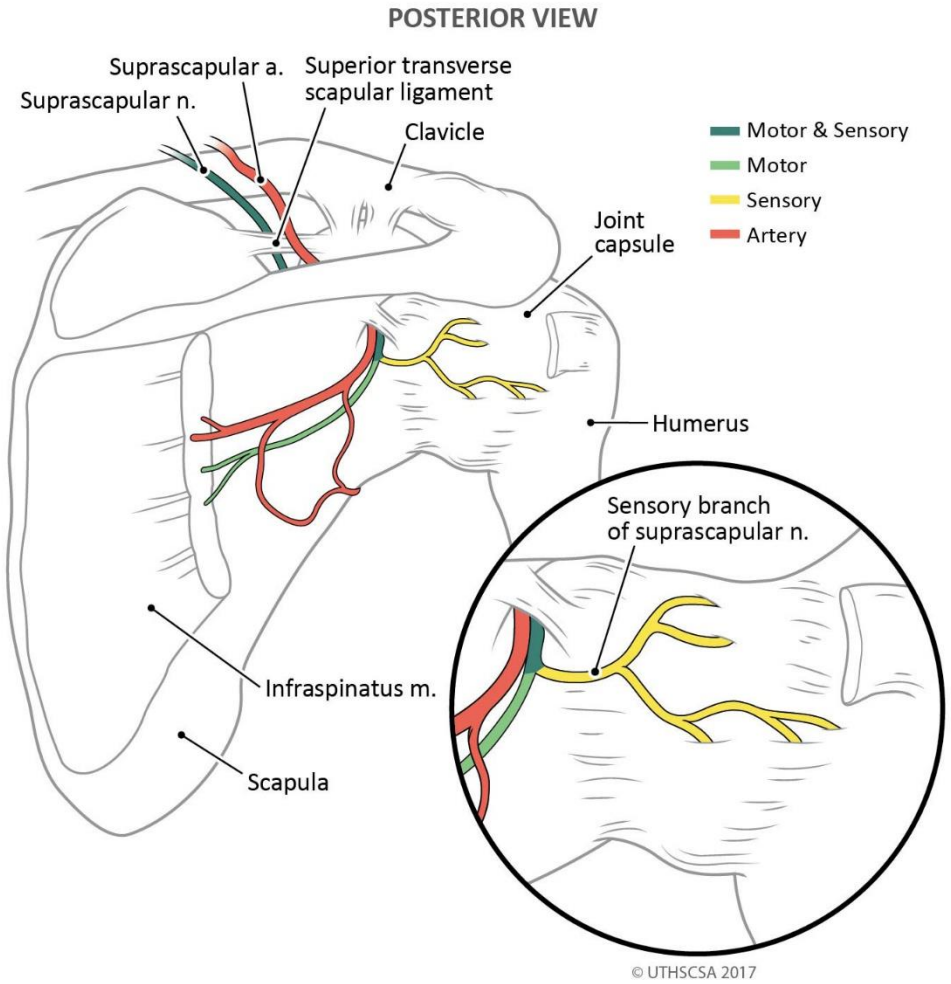


Aszmann OC, et al. Clin Orthop Relat Res. 1996 Sep;(330):202-7.

Suprascapular Nerve (SN) – Posterior View



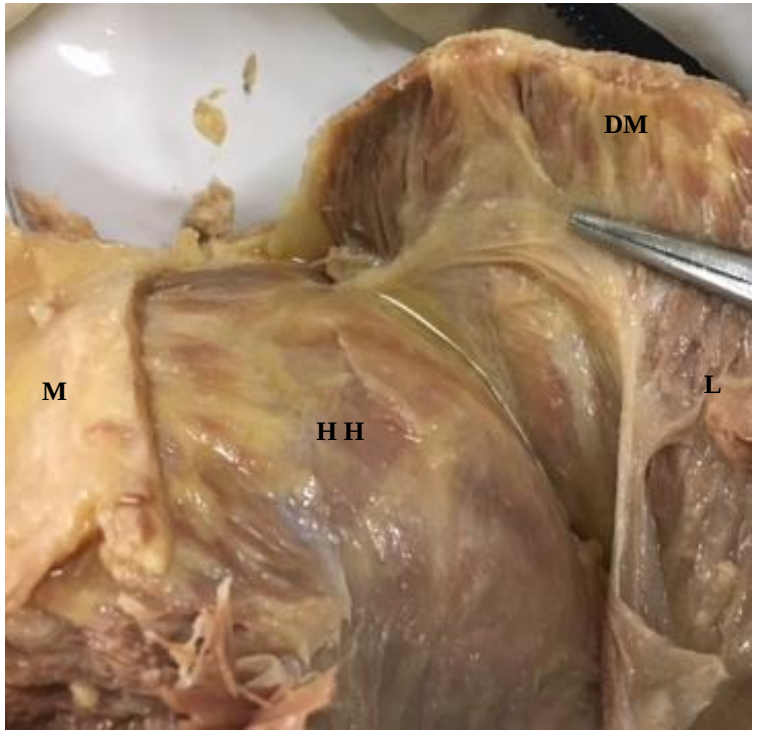


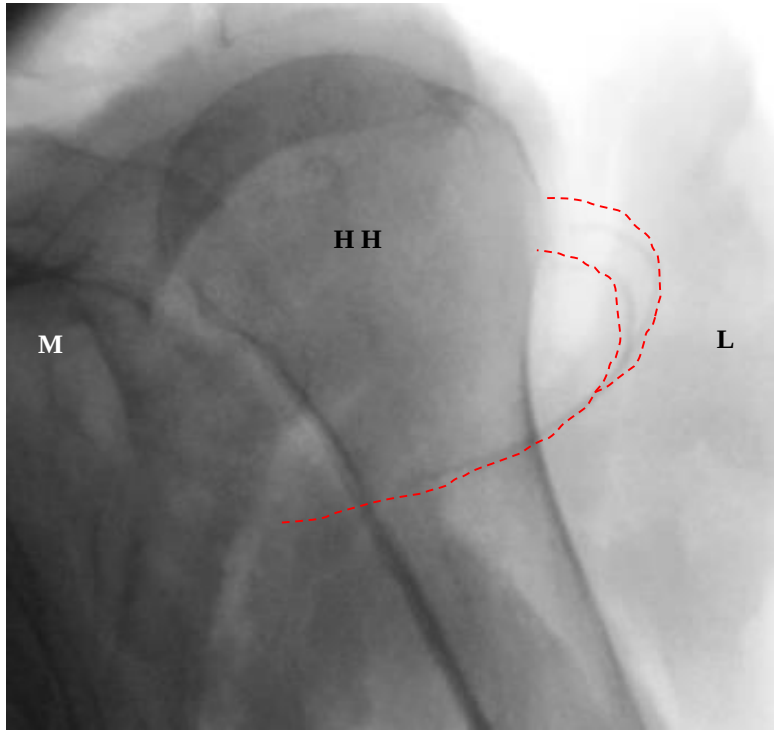


Legend: SS - Supraspinatus; IS - Infraspinatus; SGN – Spinoglenoid Notch; M – Medial; L - Lateral

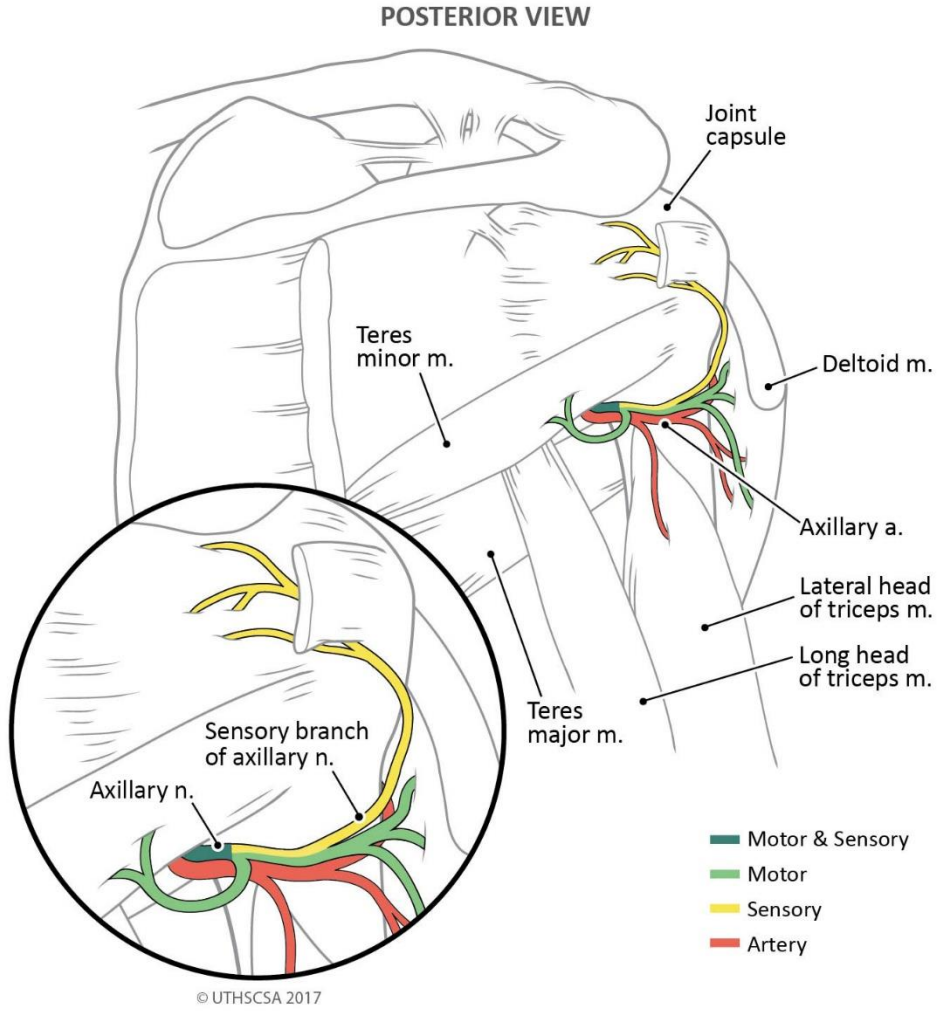
Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.

Axillary Nerve (AN) – Posterior View





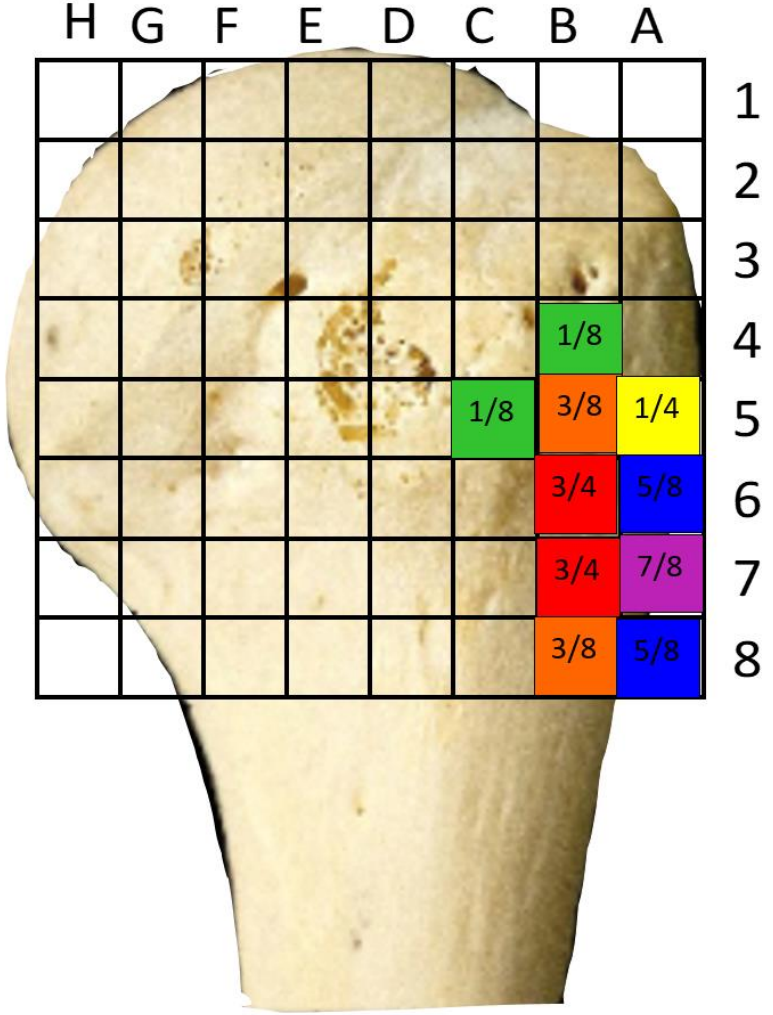
Legend: DM – Deltoid Muscle; HH – Humeral Head;
M – Medial; L - Lateral



Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.

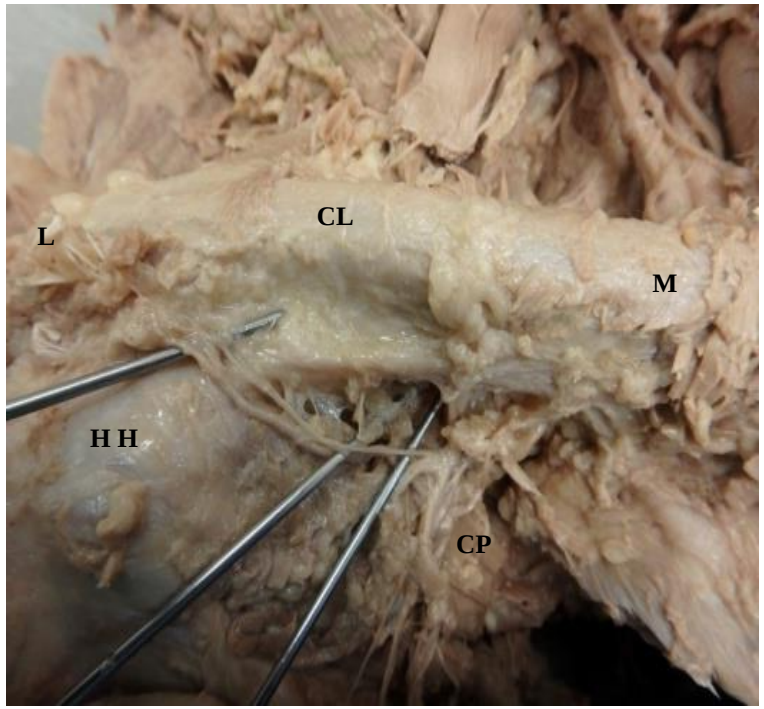
Frequency Map for Distal Branch of Posterior div. Axillary N

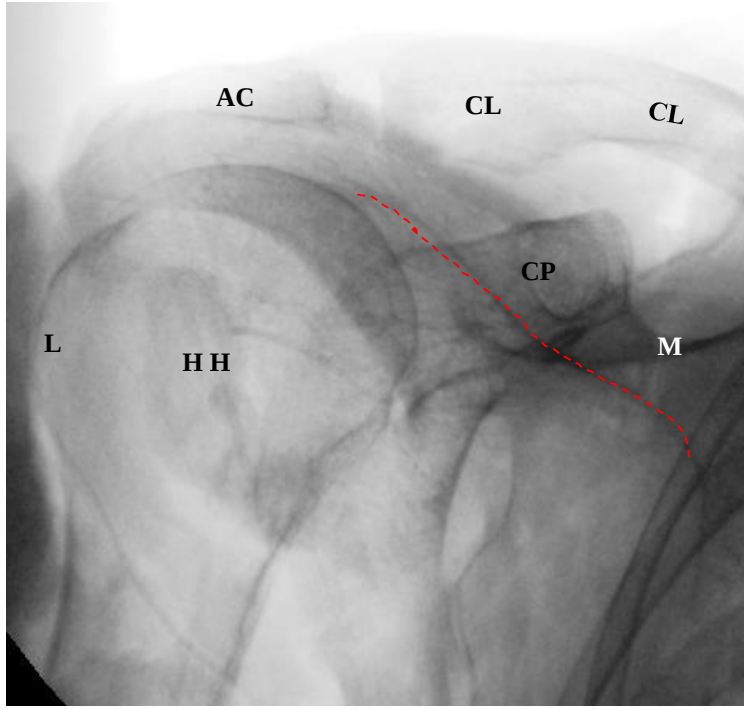
UT Health San Antonio

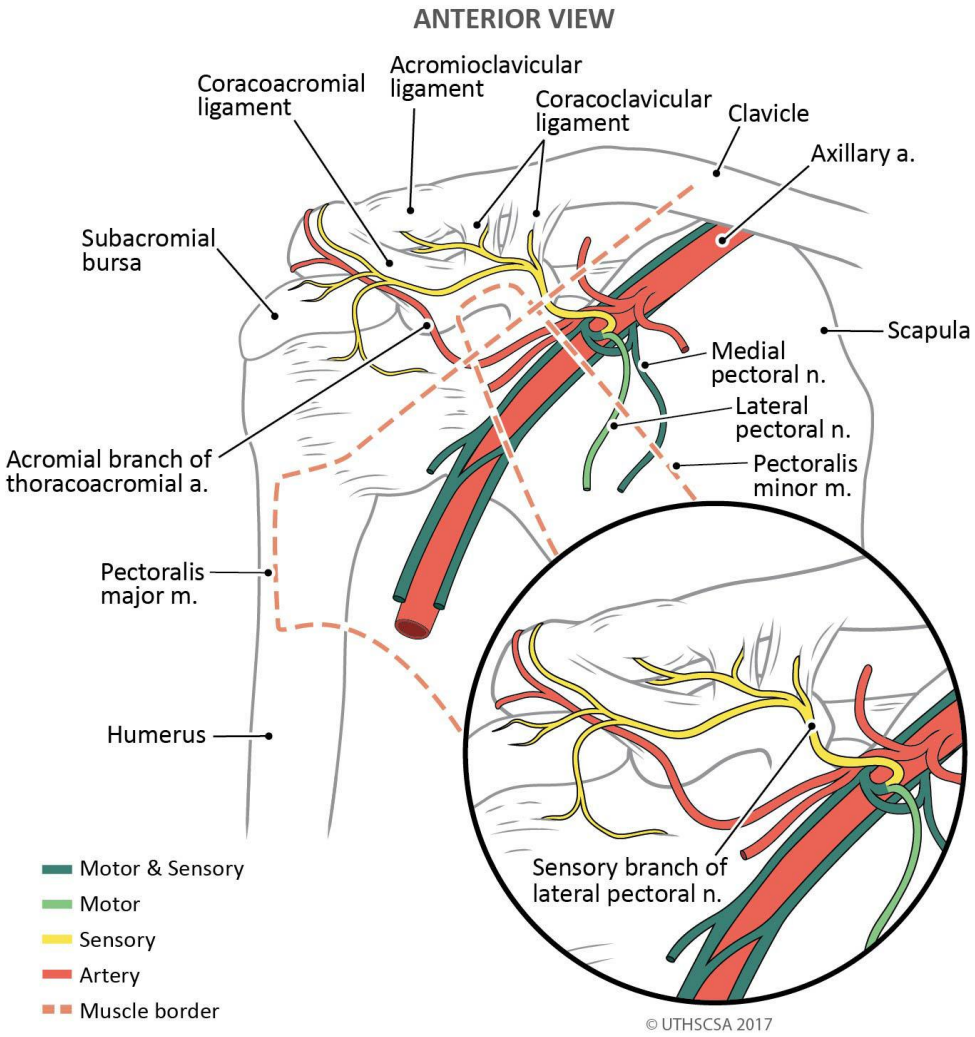


Bickelhaupt B, Eckmann MS, Brennick C, UT Health San Antonio, 2018

Lateral Pectoral Nerve (LPN) – Anterior View





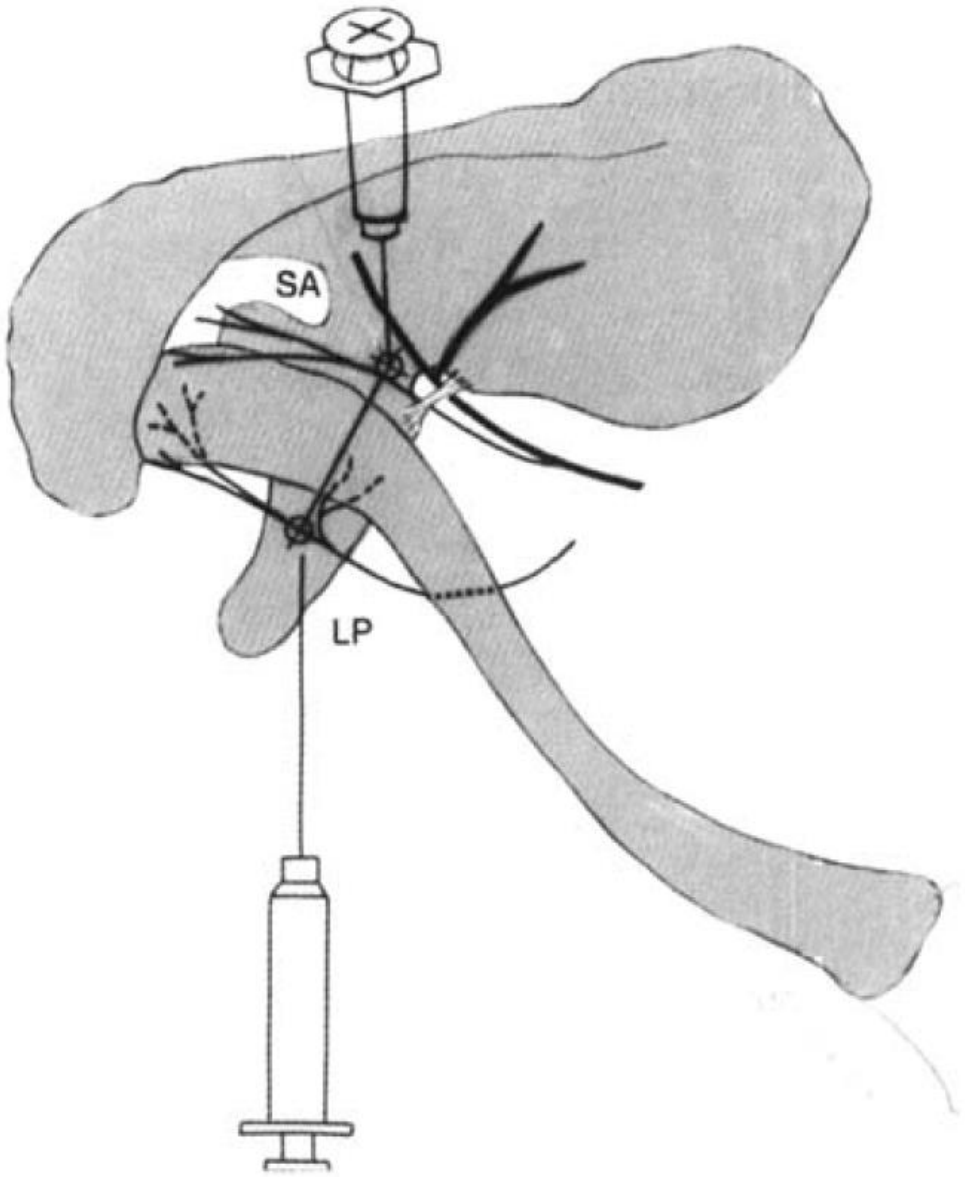


Legend: CL - Clavicle; HH – Humeral Head; CP – Coracoid Process; M – Medial; L - Lateral

Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.

Lateral Pectoral Nerve Block

- Indications
  - Anterior superior shoulder capsule, AC joint, lateral clavicle, subacromial bursa
- Landmarks
  - Deltopectoral groove
  - Clavicle
  - Coracoid Process
- Technique
  - At confluence of these 3 landmarks
  - Medial aspect of coracoid
  - Just under the clavicle
  - (Upper subscapular N can be reached 2 cm beyond and lateral)
- Ultrasound Guided
  - Has been described for breast surgery but techniques appear proximal to articular fibers



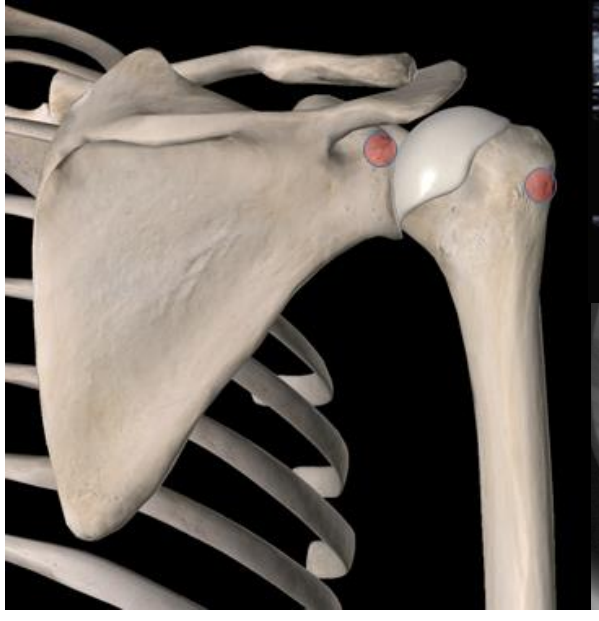
Aszmann OC, et al. Clin Orthop Relat Res. 1996 Sep;(330):202-7.

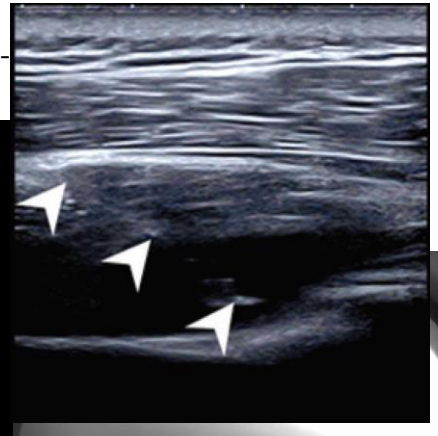
New Blocks and Approaches: Shoulder

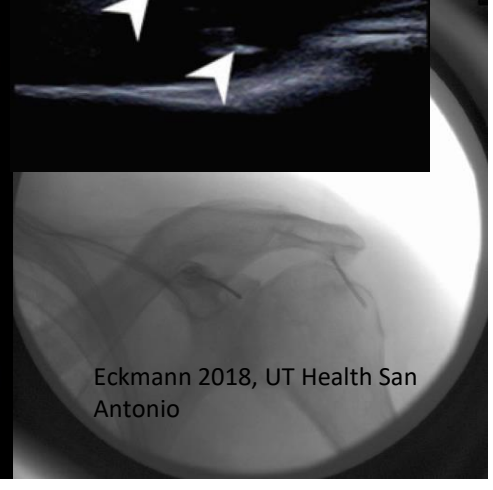
Posterior

- Access to Suprascapular Nerve via Spinoglenoid Notch, Fluoro or U/S
- Access to Axillary articular branches

Wee TC, Wu CH. J Med Ultrasound. 2018 Jul-Sep;26(3):166-167.





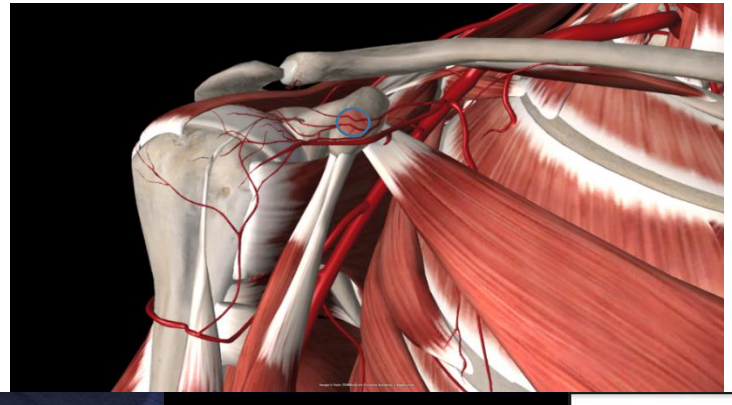


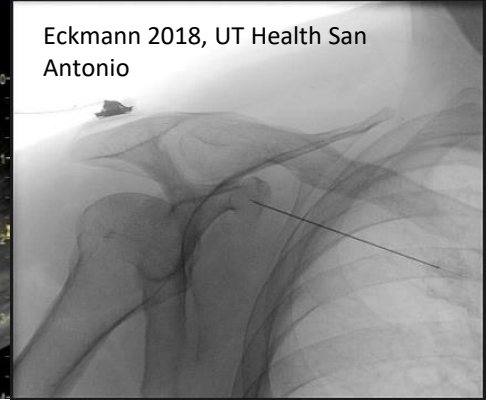
Eckmann 2018, UT Health San Antonio

Anterior

- Directed Lateral pectoral nerve block accessible over coracoid process[1]

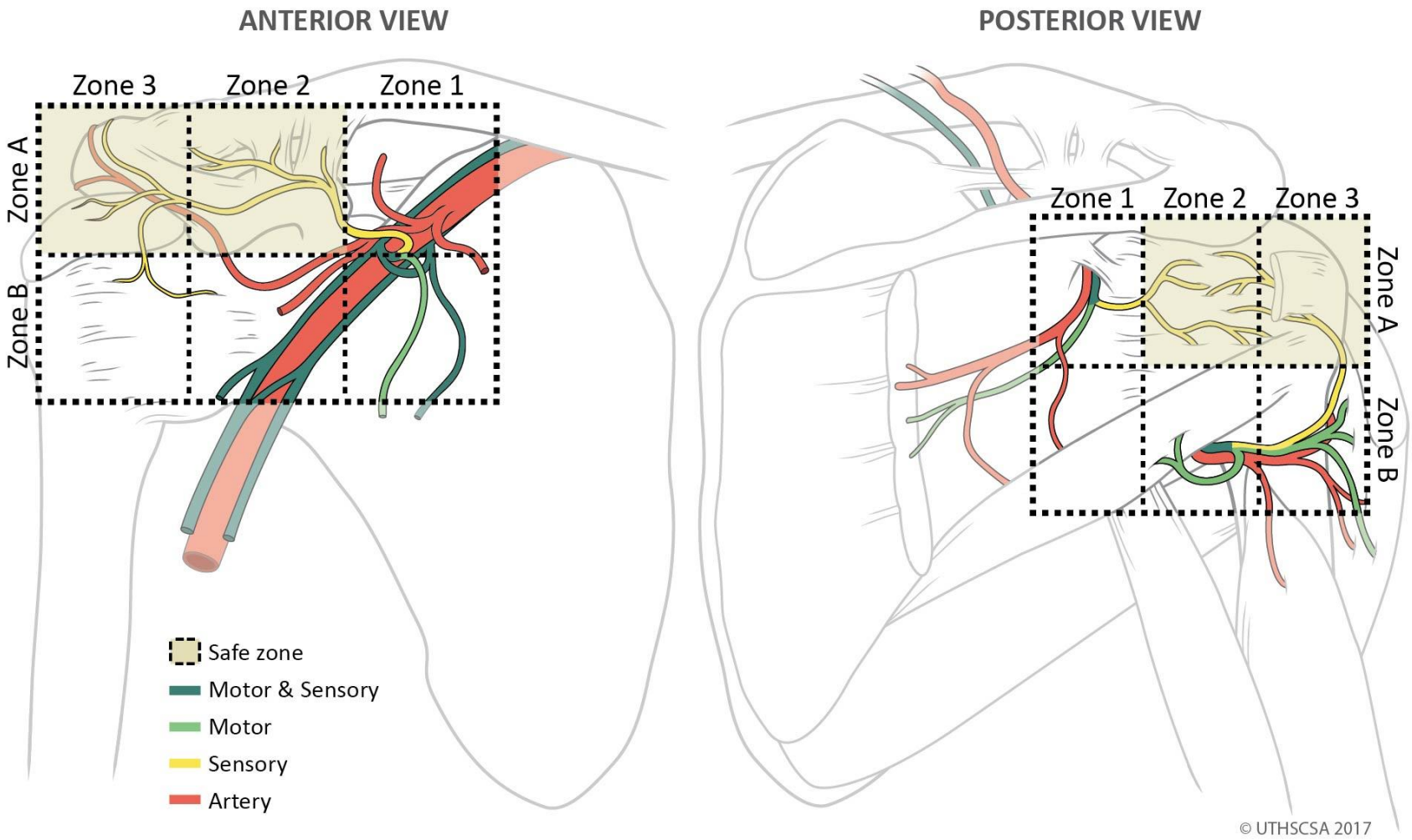
1. Aszmann OC, et al. Clin Orthop Relat Res. 1996 Sep;(330):202-7.





Eckmann 2018, UT Health San Antonio

Locations With Complete Motor Sparing Potential



Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.

Chronic Shoulder Pain: Complex Etiology and Diverse Treatments

- Significant Burden
- NSAIDS
- Physical Therapy
- Steroid Injections
- Capsular Dilation
- Pulsed Radiofrequency
- Continuous Radiofrequency
- Surgery

Zheng XQ, Li K, Wei YD, Tie HT, Yi XY, Huang W. Nonsteroidal anti-inflammatory drugs versus corticosteroid for treatment of shoulder pain: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2014 Oct;95(10):1824-31.

Sun Y, Chen J, Li H, Jiang J, Chen S. Steroid Injection and Nonsteroidal Anti-inflammatory Agents for Shoulder Pain: A PRISMA Systematic Review and Meta-Analysis of Randomized Controlled Trials. Medicine (Baltimore). 2015 Dec;94(50):e2216.

Sun Y, Lu S, Zhang P, Wang Z, Chen J. Steroid Injection Versus Physiotherapy for Patients With Adhesive Capsulitis of the Shoulder: A PRIMSA Systematic Review and Meta-Analysis of Randomized Controlled Trials. Medicine (Baltimore). 2016 May;95(20):e3469.

Xiao RC, Walley KC, DeAngelis JP, Ramappa AJ. Corticosteroid Injections for Adhesive Capsulitis: A Review. Clin J Sport Med. 2017 May;27(3):308-320.

Wu YT, Ho CW, Chen YL, Li TY, Lee KC, Chen LC. Ultrasound-guided pulsed radiofrequency stimulation of the suprascapular nerve for adhesive capsulitis: a prospective, randomized, controlled trial. Anesth Analg. 2014 Sep;119(3):686-92.

Liu A, Zhang W, Sun M, Ma C, Yan S. Evidence-based Status of Pulsed Radiofrequency Treatment for Patients with Shoulder Pain: A Systematic Review of Randomized Controlled Trials. Pain Pract. 2016 Apr;16(4):518-25.

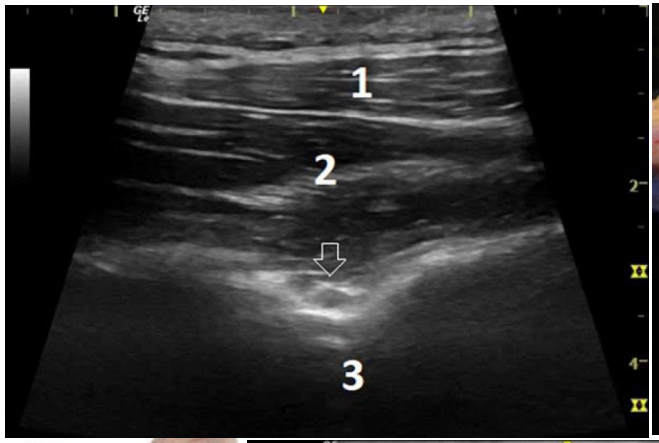
Simopoulos TT, Nagda J, Aner MM. Percutaneous radiofrequency lesioning of the suprascapular nerve for the management of chronic shoulder pain: a case series. J Pain Res. 2012;5:91-7.

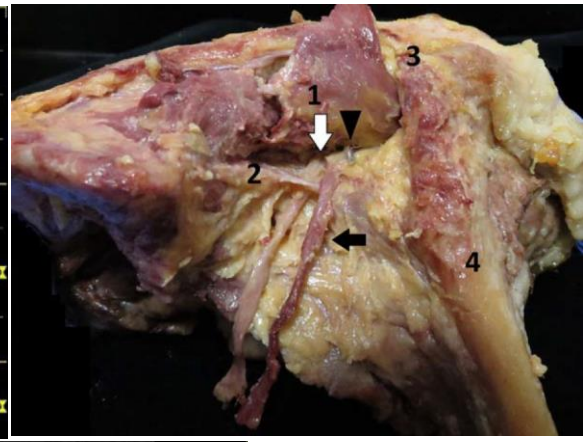
Shoulder Nerve Ablation – Emerging Knowledge

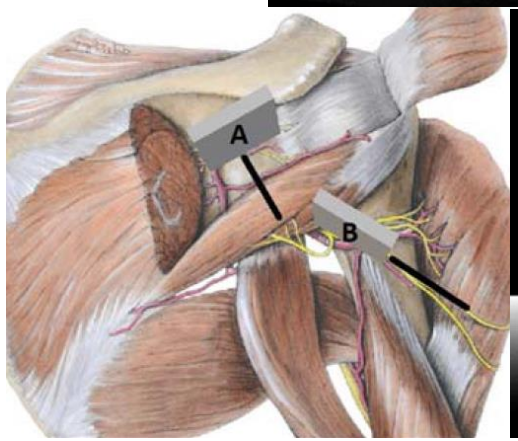
- The shoulder is the most complex major joint with a high degree of mobility, many contributing muscles, and many innervating nerves.
- Chronic shoulder pain may stem from a variety of causes including rotator cuff disease, glenohumeral joint (GHJ) osteoarthritis, nerve injuries, and capsulitis.
- The suprascapular, axillary, lateral pectoral, and subscapular nerves are known to innervate the GHJ[1,2]. Other nerves may also contribute theoretically by Hiltons Law of joint innervation. Articular branch nerves have been described and may be future clinical targets[3].
- Case series exist of main suprascapular nerve ablation to palliate shoulder pain in patients with limited functional use of the shoulder[3]. While weakness of the shoulder is a logical complication, patients can retain or improve function due to reduced pain and compensation from other muscles.

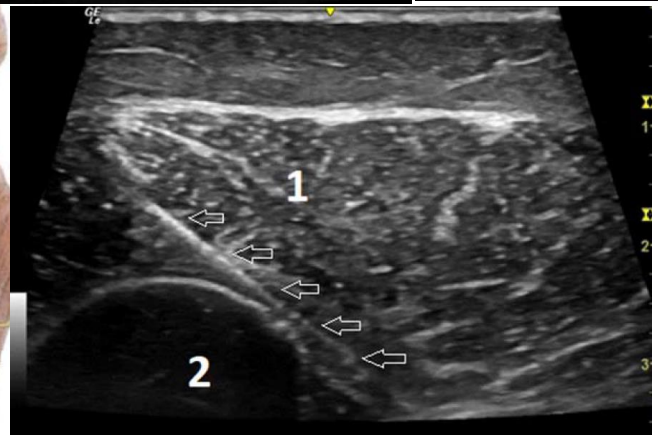
1. Eckmann MS. Reply to Dr Price. Reg Anesth Pain Med. 2018 Apr;43(3):334-335.
2. Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.
3. Simopoulos TT, Nagda J, Aner MM. Percutaneous radiofrequency lesioning of the suprascapular nerve for the management of chronic shoulder pain: a case series. J Pain Res. 2012;5:91-7.

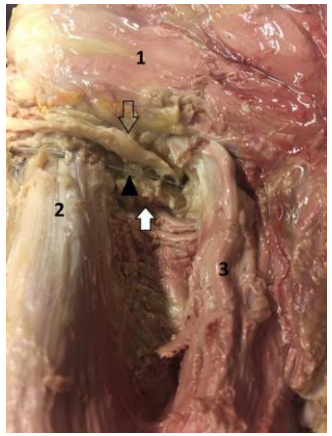
Emerging Area – Peripheral Neuromodulation for Subacute and Chronic Shoulder Pain







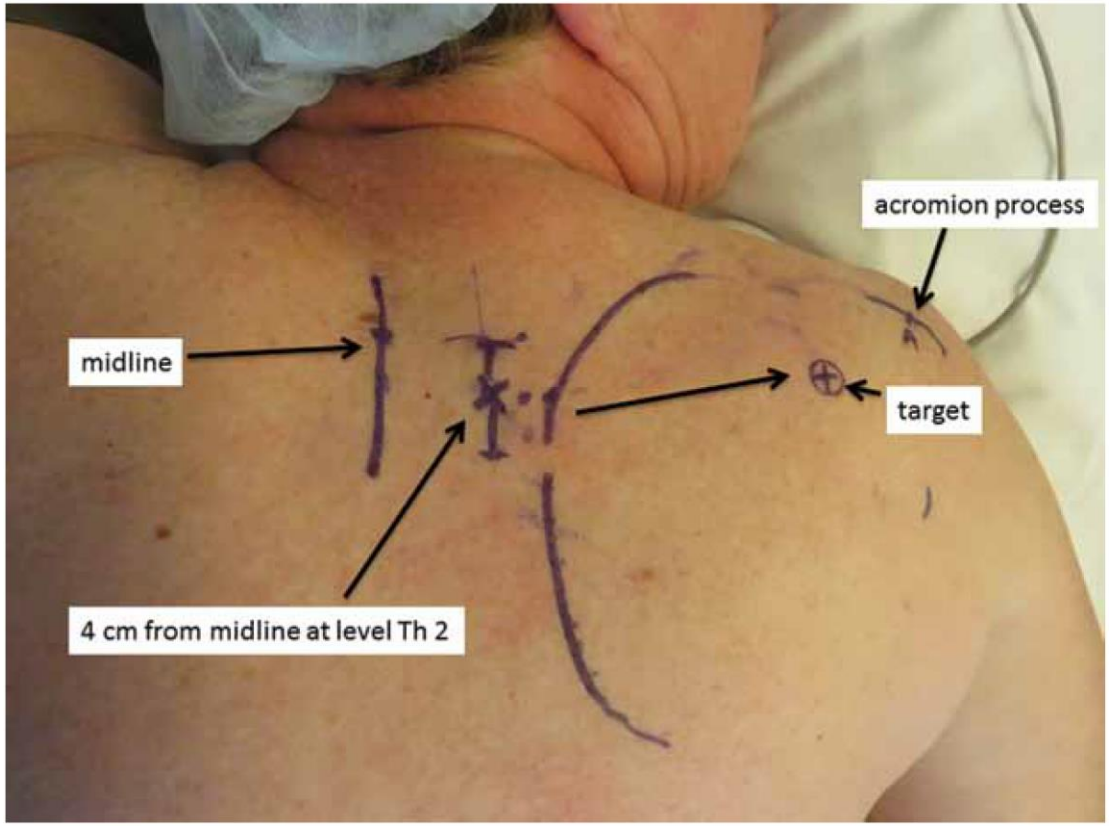


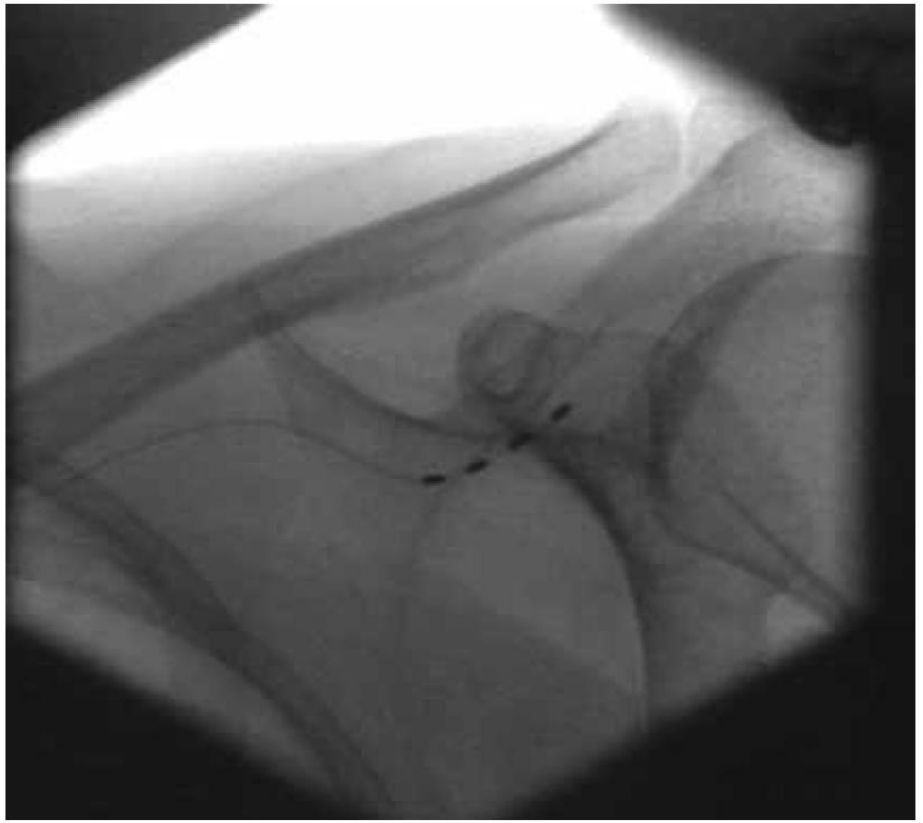


- Multiple active clinical trials of Axillary Nerve stimulation for post-stroke shoulder pain
- RCTs for nerve and EMG guided intramuscular simulation have been completed

1. Gofeld M, Agur A. Peripheral Nerve Stimulation for Chronic Shoulder Pain: A Proof of Concept Anatomy Study. Neuromodulation. 2018 Apr;21(3):284-289.
2. Nguyen VQ, Bock WC, Groves CC, Whitney M, Bennett ME, Lechman TE, Strother R, Grill JH, Stager KW, Chae J. Fully implantable peripheral nerve stimulation for the treatment of hemiplegic shoulder pain: a case report. Am J Phys Med Rehabil. 2015 Feb;94(2):146-53.
3. Chae J, Wilson RD, Bennett ME, Lechman TE, Stager KW. Single-lead percutaneous peripheral nerve stimulation for the treatment of hemiplegic shoulder pain: a case series. Pain Pract. 2013 Jan;13(1):59-67.
4. Wilson RD, Gunzler DD, Bennett ME, Chae J. Peripheral nerve stimulation compared with usual care for pain relief of hemiplegic shoulder pain: a randomized controlled trial. Am J Phys Med Rehabil. 2014 Jan;93(1):17-28.
5. Wilson RD, Bennett ME, Nguyen VQC, Bock WC, O'Dell MW, Watanabe TK, Amundson RH, Hoyen HA, Chae J. Fully Implantable Peripheral Nerve Stimulation for Hemiplegic Shoulder Pain: A Multi-Site Case Series With Two-Year Follow-Up. Neuromodulation. 2018 Apr;21(3):290-295.

Case Reports





Erkan Kurt, MD1, Tess van Eijk, Dylan Henssen, Inge Arnts, and Monique Steegers. Neuromodulation of the Suprascapular Nerve. Pain Physician 2016; 19:E235-E239

- **2 Year Data, multicenter trial**
- **Chronic Hemiplegic Shoulder Pain**
- **Axillary Motor Point Stimulation**
- **Sham Controlled Trial Step**
- **5 completers of 28 recruits**
- **Significant improvement in pain interference >50% at 12 months**
- **4/5 >50% pain improvement 24 months**
- **Improved Movement**

Table 2. Outcome Assessments for Implant Stage Participants, $N = 5$.

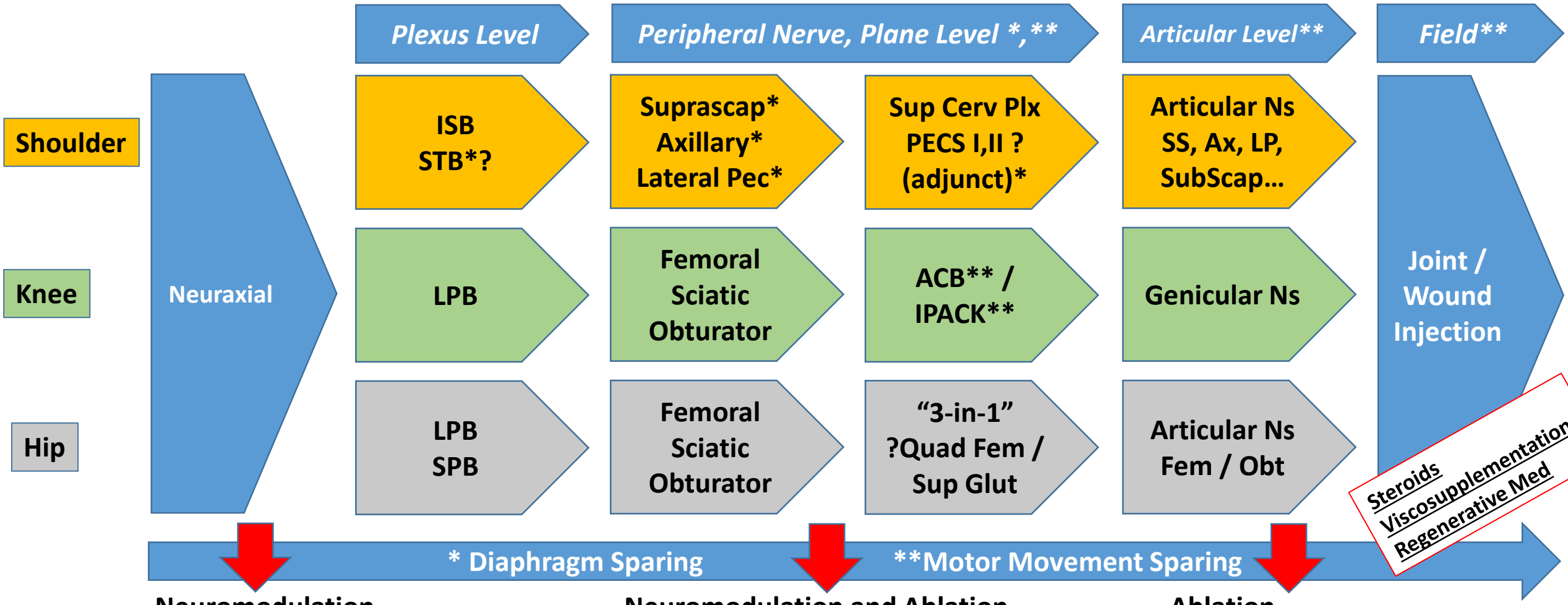
	Baseline	End of Sham	End of Trial	6 months	12 months	24 months
Worst pain 7 days (±SE)	8.2	5.2 (± 0.7)	2.4 (±0.7)	1.6 (±0.7)	0.8 (±0.7)	1.6 (±0.7)
Pain interference 7 days (±SE)	5.8	4.2 (±0.4)	1.4 (±0.4)	0.3 (±0.4)	0.1 (±0.4)	0.4 (±0.4)
External rotation ROM (degrees)	69.2	96.6 (±9.1)	134.2 (±9.1)	141.2 (±9.1)	151.4 (±9.1)	
SF-36v2 (±SE)						
Physical functioning	28.9	30.5 (±6.1)	33.4 (±6.1)	31.3 (±6.1)	31.3 (±6.1)	
Role-limitations physical	29.4	35.6 (±4.2)	38.3 (±4.2)	37.1 (±4.2)	30.6 (±4.2)	
Bodily pain	30.6	34.8 (±3.4)	42.0 (±3.4)	45.1 (±3.4)	50.1 (±3.4)	
General health	42.4	38.7 (±4.5)	38.7 (±4.5)	41.7 (±4.5)	38.0 (±4.5)	
Vitality	46.0	47.2 (±3.7)	44.8 (±3.7)	51.4 (±3.7)	50.2 (±3.7)	
Social functioning	39.2	42.4 (±4.2)	47.8 (±4.2)	47.8 (±4.2)	44.6 (±4.2)	
Role-emotional	35.2	34.5 (±7.0)	39.0 (±7.0)	47.4 (±7.0)	43.6 (±7.0)	
Mental health	39.6	46.3 (±4.6)	46.3 (±4.6)	50.7 (±4.6)	47.9 (±4.6)	

The trial stage consisted of a three-week blinded sham introductory period and a three-week active stimulation period.
SE, standard error; PNS, peripheral nerve stimulation; VGRS, Visual Graphic Rating Scales.

1. Wilson RD, Bennett ME, Nguyen VQC, Bock WC, O'Dell MW, Watanabe TK, Amundson RH, Hoyen HA, Chae J. Fully Implantable Peripheral Nerve Stimulation for Hemiplegic Shoulder Pain: A Multi-Site Case Series With Two-Year Follow-Up. Neuromodulation. 2018 Apr;21(3):290-295.

Chronic Pain Applications

ISB (interscalene block); STB (superior trunk block);
LPB (lumbar plexus block); ACB (adductor canal block);
LFCN (lateral femoral cutaneous nerve); IPACK (infiltration between popliteal artery and capsule of knee); PECS (pectoralis block)



Neuromodulation

- *Spinal Cord Stimulation*
- *Dorsal Root Ganglion Stimulation*
- *Intrathecal Drug Delivery*
- *Deep Brain Stimulation*

Neuromodulation and Ablation

- *Pulsed Radiofrequency Ablation (RFA)*
- *Standard and Cooled RFA (SRFA, CRFA)*
- *Cryoablation, Chemoneurolysis*
- *Peripheral Nerve Stimulation*

Ablation

- *Genicular*
- *Fem/Obt*
- *? Shoulder articular*
- Field/ Cutaneous Stimulation

Summary and Future Directions

- **Further Pre-clinical Validation for Joint Applications (Variability, Approaches, Other Nerves) needed.**
  - Quantitative Frequency Maps, Branches, Insertions/Planes, Landmarks
  - Newly understood Nerves/Contributions?
- **Clinical Efficacy, Safety for Important Outcomes in Acute and Chronic must be studied and demonstrated**
  - Block combination matrix [Peripheral, Plane, Plexus]
  - Pain and Medication reduction
  - Avoidance of Weakness, Respiratory Compromise
  - Promotion of Mobility, Joint Function
- **Melding of Strategies for Advanced Acute/Subacute Pain Management**
  - Perioperative Joint Ablation?
  - Postoperative Peripheral Nerve Stimulation?