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
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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

**Shoulder**
- Proximal:
  - Dermatome
  - Myotome/Sclerotome
  - Osteotome/Capsulotome
  - Motor Block

**Knee**
- Proximal:
  - Dermatome
  - Motor Block
- Progressive loss of:
  - Cutaneous, muscular anesthesia.

**Hip**
- Proximal:
  - Dermatome
  - Myotome/Sclerotome
  - Osteotome/Capsulotome
  - Motor Block

**Neuraxial**
- ISB
  - STB
- LPB

**Plexus Level**
- ISB/STB
- Suprascap
  - Axillary
  - Lateral Pec
- Femoral
  - Sciatic
  - Obturator
- ACB** / IPACK**

**Peripheral Nerve, Plane Level ***
- Suprascap*
- Axillary*
- Lateral Pec*
- Femoral
- Sciatic
- Obturator
- Sup Cerv Plx
  - PECS I,II ? (adjunct)*
- “3-in-1”
  - Quad Fem / Sup Glut

**Articular Level**
- Articular Ns
  - SS, Ax, LP, SubScap...
- Genicular Ns
  - Articular Ns
  - Fem / Obt

**Field**
- Joint / Wound Injection

**Field**
- 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)

* Diaphragm Sparing  **Motor Movement Sparing

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**


- **Interscalene Block**


- **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.‡

**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.

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.
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

Motor Sparing Blocks: Diaphragm

- **Superior Trunk Approach**
  


  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**
  


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

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


• “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.
Lateral pectoral nerve\textsuperscript{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\textsuperscript{4} •

Based on Hilton’s Law, at least 15 peripheral nerves or ventral rami could contribute to the shoulder •

Hilton’s Law Applied to Glenohumeral Joint

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

### Suprascapular Nerve

<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Specimens</th>
<th>Sample Size</th>
<th>Articular branch innervation and pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6) Aszmann et al, 1995</td>
<td>Fresh-frozen adult cadavers</td>
<td>25 shoulders</td>
<td>After entering suprascapular notch, the suprascapular n. sends lateral articular branches to the coracoclavicular ligaments.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>After giving a muscular branch to the suprascapular m., the suprascapular n. gives lateral articular branches to the posterior joint capsule.</td>
</tr>
<tr>
<td>(20) Ebraheim et al, 2010</td>
<td>Embalmed adult cadavers</td>
<td>12 shoulders</td>
<td>Articular branches came off the main suprascapular n. after passing through the notch to innervate the acromioclavicular joint and subacromial bursa.</td>
</tr>
<tr>
<td>(21) Vorster et al, 2008</td>
<td>Embalmed adult cadavers</td>
<td>31 shoulders</td>
<td>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.</td>
</tr>
</tbody>
</table>

### Axillary Nerve

<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Specimens</th>
<th>Sample Size</th>
<th>Articular branch innervation and pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6) Aszmann et al, 1995</td>
<td>Fresh-frozen adult cadavers</td>
<td>25 shoulders</td>
<td>As axillary n. crosses subscapular m., it gives articular branch to inferior-anterior joint capsule</td>
</tr>
<tr>
<td>(18) Gelber et al, 2006</td>
<td>Fresh-frozen and embalmed adult cadavers</td>
<td>61 shoulders</td>
<td>As axillary n. passes through quadrangular space, wraps laterally around humeral neck, pierces deltoid, and then articular branches continue to pierce IGHL (13.11%).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>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%).</td>
</tr>
<tr>
<td>(19) Nasu et al, 2014</td>
<td>Embalmed adult cadavers</td>
<td>20 shoulders</td>
<td>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 humerus at intertubercular sulcus (15%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>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%).</td>
</tr>
</tbody>
</table>

### Lateral Pectoral Nerve

<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Specimens</th>
<th>Sample Size</th>
<th>Articular branch innervation and pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>(11) Akita et al, 2002</td>
<td>Unspecified cadavers</td>
<td>125 shoulders</td>
<td>The lateral pectoral n. gives an articular branch to the shoulder joint after passing over the acromion.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lateral pectoral n. passes between coracoclumeral and coracoclavicular ligaments to innervate subacromial bursa and anterior acromioclavicular ligament.</td>
</tr>
<tr>
<td>(5) Nam et al, 2016</td>
<td>Unembalmed cadavers</td>
<td>43 shoulders</td>
<td>Lateral pectoral n. gives an articular branch along the superomedial margin of the deltoïd muscle, along anterior coracoclavicular ligament then piercing the coracoacromial ligament to enter the shoulder joint (67.4%).</td>
</tr>
</tbody>
</table>
Neurologic Innervation: Articular Branches

Anterior

- Subscapular Branches
- Axillary Nerve (Anterior Branch)
- 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

Suprascapular Nerve (SN) – Posterior View

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

Axillary Nerve (AN) – Posterior View

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

Frequency Map for Distal Branch of Posterior div. Axillary N
Lateral Pectoral Nerve (LPN) – Anterior View

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

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

New Blocks and Approaches: Shoulder

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

**Anterior**
- Directed Lateral pectoral nerve block accessible over coracoid process\(^1\)

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Locations With Complete Motor Sparing Potential

Chronic Shoulder Pain: Complex Etiology and Diverse Treatments

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


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\textsuperscript{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\textsuperscript{3}.

• Case series exist of main suprascapular nerve ablation to palliate shoulder pain in patients with limited functional use of the shoulder\textsuperscript{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.

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

Case Reports

• 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.

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

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.

**Chronic Pain Applications**

**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

**Diaphragm Sparing**
- 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)

**Motor Movement Sparing**
- Shoulder
- Knee
- Hip

**Joint / Wound Injection**
- Steroids
- Viscosupplementation
- Regenerative Med
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?