Pediatric Regional Anesthesia/Analgesia

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CME Requirements: Objectives

- Review clinical applications of regional anesthetic techniques in children.
- Discuss indications and safety considerations for these techniques.
- Consider modalities, particularly ultrasound, used in these techniques.
CME Requirements: Disclosures

I have no relevant financial relationships with any commercial interests.

Vanderbilt is a site for studies as below.

Site investigator for industry-sponsored pediatric licensing studies including:

IR/ER oxymorphone - Opana®, ENDO
ER oxycodone - OxyContin®, Purdue Pharma
IV acetaminophen - Orfimev®, Mallinckrodt
ER hydromorphone - Exalgo®, Mallinckrodt
Tapentadol – Nucynta®, Janssen
(IV dexmedetomidine – Precedex®, Hospira)
CME Requirements: Off-Label

Many anesthetic agents and techniques are widely used in children;
Many such agents and techniques are NOT approved for such use.

Much of current pediatric anesthetic practice, and most of current pediatric pain practice, is still largely off-label/investigational.
Benefits/Indications
Chelly 2004, Hadzik 2007

• Largely limited to limb & girdle procedures
• Awake/sedated during surgery in adults
• Hemodynamic stability (ASA $\geq 3$)
• Limited sensory and/or motor block
• Postoperative analgesia
• Early discharge
General Contraindications

• Absolute
  – Local anesthetic allergy, local infection, preoperative progressive neuro-impairment, postoperative neuro-monitoring is required, surgical nerve repair
  – Uncontrolled seizure
  – Active bleeding due to coagulopathy or anticoagulation
  – Refusal, uncooperative
  – Lack of resources for appropriate follow-up

• Stable coagulopathy & anticoagulation therapy
  – Relative contraindication for superficial PNB
  – Deeply located nerves: paravertebral, gluteal sciatic NB is controversial

• Risks/benefits should be discussed with patients & surgeon
• Plexus, paravertebral LSB and PNB in the anticoagulated patients:
  – Risks remains undefined
  – Recommendations same as with neuraxis for insertion and removal of catheter
  – Grade 1C (case series)

• Single-injection superficial PNB: Controversial
RA in Anti-coagulated Patient I

Benzon, HT, see next slide

I. Antiplatelet medications
   1. Aspirin, NSAIDs, Cox-2 inhibitors
      Surgery: May continue
      Pain Clinic: ASA preferred stopped >2-3 d in thoracic/cervical epidurals
   2. Thienopyridine derivatives
      a) Clopidogrel (Plavix): discontinue for 7 d
      b) Ticlopidine (Ticlid): discontinue for 14 d
      DO NOT perform a neuraxial block in pts. On more than 1 antiplatelet drug
      If a neuraxial or deep plexus block has to be performed in pts. Whose clopidogrel
      was discontinued < 7 d, then a P2Y12 assay should be performed.
   3. GPIIB/IIIA Inhibitors: Time to normal platelet aggregation
      a) Abciximab (ReoPro): 48 h
      b) Eptifibatide (Integrilin): 8 h
      c) Tirofiban (Aggrastat): 8 h

II. Warfarin
    Check INR; discontinue 4-5 d
    INR < 1.4 before neuraxial block or epidural catheter removal

III. Heparin
    1. Subcutaneous heparin (5000 U SC q12h)
       SC heparin is not a contraindication for a neuraxial block
       Neuraxial block should preferably be performed before SC heparin is given
       Risk of decreased platelet count with SC heparin > 5 d
    2. Intravenous heparin
       Neuraxial block: 2-4 h after the last IV heparin dose
       Wait > 1 h after neuraxial block before giving IV heparin

IV. Low molecular weight heparin (LMWH)
    No concomitant antiplatelet medication, heparin or dextran
    Time interval between placement/removal of catheter after last dose:
    a) Enoxaparin (Lovenox): 0.5 mg/kg bid (prophylactic dose): 12 h
    b) 24 h interval:
       Enoxaparin (Lovenox) 1 mg/kg bid
       Enoxaparin (Lovenox) 1.5 mg/kg qd
       Dalteparin (Fragmin) 120 U/kg bid, 200 U/kg qd
       Tinzaparin (Innohep) 175 U/kg qd
    LMWH-Postop: Should not be started until 24 h postsurgery
    LMWH should not be given until ≥ 2 h after epidural catheter removal
V. Specific Xa inhibitor: Fondaparinux (Arixtra)
   ASRA: If neuraxial procedure has to be performed recommend single
   needle, atraumatic placement, avoid indwelling catheter
   EXPERT Study: Epidural placement or catheter removal: 36 h after stop
   Fondaparinux (Half lives); subsequent dose 12 h after catheter removal.

VI. Fibrinolytic/Thrombolytic drugs (Streptokinase, alteplase [TPS])
   Recommended interval: 10 d
   No data on safety interval for performance of neuraxial procedure

VII. Thrombin Inhibitors
   Desirudin (Revasc)
   Lepirudin (Refludan)
   Bivalirudin (Angiomax)
   Argatroban (Acova)
   Anticoagulant effects last 3 h; monitored by aPTT

VIII. Herbal therapy
   Mechanism of anticoagulant effect and time to normal hemostasis:
   Garlic: inhibits platelet aggregation, increased fibrinolysis; 7d
   Gingko: inhibits platelet-activating factor; 36h
   Ginseng: increased PT and PTT; 24 h

Benzon, HT, 20/09/2013
Placement of Blocks Awake vs. Asleep

• In pediatric population, the placement of all types of regional anesthetic techniques under general anesthesia is considered the standard of care
  – Supported by all the pediatric epidemiological studies on RA

• Multiple recent large reviews suggest safety for the use of deep sedation/general anesthesia for pediatric patients


Ultrasound ± Nerve Stimulator

### Table 4. Use of Localizing Techniques for Single-Injection Upper Extremity Blocks

<table>
<thead>
<tr>
<th>Technique</th>
<th>Total</th>
<th>None</th>
<th>Nerve Stimulator</th>
<th>Fluoroscopy</th>
<th>Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interscalene/parascalenae</td>
<td>80</td>
<td>2</td>
<td>16 (20%)</td>
<td>0</td>
<td>78 (98%)</td>
</tr>
<tr>
<td>Supravclavicular</td>
<td>164</td>
<td>2</td>
<td>22 (13%)</td>
<td>0</td>
<td>158 (96%)</td>
</tr>
<tr>
<td>Intercostal</td>
<td>40</td>
<td>1</td>
<td>11 (28%)</td>
<td>0</td>
<td>38 (95%)</td>
</tr>
<tr>
<td>Axillary</td>
<td>99</td>
<td>14</td>
<td>12 (12%)</td>
<td>1</td>
<td>77 (78%)</td>
</tr>
<tr>
<td>Musculocutaneous</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3 (60%)</td>
</tr>
<tr>
<td>Elbow</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>Wrist</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>58</td>
<td>33</td>
<td>2 (3%)</td>
<td>3</td>
<td>19 (33%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>455</td>
<td>61</td>
<td>64 (14%)</td>
<td>4</td>
<td>375 (82%)</td>
</tr>
</tbody>
</table>

More than 1 technology can be used for a block, thus totals may exceed 100%.

### Table 5. Use of Localizing Techniques for Single-Injection Lower Extremity Blocks

<table>
<thead>
<tr>
<th>Technique</th>
<th>Total</th>
<th>None</th>
<th>Nerve Stimulator</th>
<th>Fluoroscopy</th>
<th>Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar plexus/psoas compartment</td>
<td>78</td>
<td>8</td>
<td>60 (77%)</td>
<td>9 (12%)</td>
<td>48 (22%)</td>
</tr>
<tr>
<td>Fascia ilioac</td>
<td>221</td>
<td>166</td>
<td>4 (2%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Femoral</td>
<td>872</td>
<td>35</td>
<td>313 (36%)</td>
<td>1 (0.1%)</td>
<td>760 (87%)</td>
</tr>
<tr>
<td>Sciatic</td>
<td>413</td>
<td>13</td>
<td>195 (47%)</td>
<td>0</td>
<td>303 (73%)</td>
</tr>
<tr>
<td>Popliteal fossa</td>
<td>319</td>
<td>11</td>
<td>151 (47%)</td>
<td>2 (0.6%)</td>
<td>265 (83%)</td>
</tr>
<tr>
<td>Saphenous</td>
<td>78</td>
<td>9</td>
<td>5 (6%)</td>
<td>0</td>
<td>65 (83%)</td>
</tr>
<tr>
<td>Other</td>
<td>325</td>
<td>119</td>
<td>36 (11%)</td>
<td>20 (6%)</td>
<td>169 (52%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2070</td>
<td>361</td>
<td>764 (33%)</td>
<td>32 (1%)</td>
<td>1619 (62%)</td>
</tr>
</tbody>
</table>

More than 1 technology can be used for a block, thus totals may exceed 100%.

### Table 6. Use of Localizing Techniques for Single-Injection Other Block Types

<table>
<thead>
<tr>
<th>Technique</th>
<th>Total blocks</th>
<th>None</th>
<th>Nerve Stimulator</th>
<th>Fluoroscopy</th>
<th>Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercostal</td>
<td>39</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>30 (77%)</td>
</tr>
<tr>
<td>Iliounitary/iliohypogastric</td>
<td>737</td>
<td>158</td>
<td>2</td>
<td>3</td>
<td>563 (76%)</td>
</tr>
<tr>
<td>Rectus sheath</td>
<td>294</td>
<td>32</td>
<td>2</td>
<td>0</td>
<td>256 (87%)</td>
</tr>
<tr>
<td>Paravertebral</td>
<td>14</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>4 (29%)</td>
</tr>
<tr>
<td>Psoas</td>
<td>230</td>
<td>224</td>
<td>0</td>
<td>0</td>
<td>2 (0.9%)</td>
</tr>
<tr>
<td>TAP</td>
<td>140</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>125 (92%)</td>
</tr>
<tr>
<td>Other</td>
<td>395</td>
<td>198</td>
<td>3</td>
<td>44</td>
<td>147 (37%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1849</td>
<td>630</td>
<td>7</td>
<td>48</td>
<td>1131 (61%)</td>
</tr>
</tbody>
</table>

TAP = transversus abdominis plane.


Intensive Review of Pediatric Anesthesia 2015
Inadvertent Intravascular Injection
Reliability of a Test dose
(multiple case series)

• Incidences 0.6 - 5.6%

• No method of test dosing is universally applicable in clinical practice under GA:
  – Lacks 100% sensitivity and 100% specificity
  – Epidurography: epidural vs. intravascular space
  – Insufficient data on reliability of ultrasound
Safe Epidural Placement

1. Limit epinephrine to 0.5-1.0 mcg/kg
2. Perform loss-of-resistance with saline, not air.
3. Prevent or promptly treat severe hypotension.
4. Consider severe hypotension after test/load dose under general anesthesia to be due to subarachnoid injection unless demonstrated otherwise.
5. Consider severe hypertension after test/load dose to indicate intraneural injection.
6. Consider use of Tsui’s nerve stimulation technique or fluoroscopy, as well as ultrasonography for infants, for cases of direct thoracic puncture under general anesthesia.
7. Inject epidural loading doses slowly in anesthetized patients.
8. Use dilute local anesthetic solutions for intraoperative epidural infusions.
9. In PACU, document the sensory and motor blockade. If blockade dense, stop the infusion and observe for regression. If no regression over the next 3 h, consider emergent spine MRI and neurosurgical consultation. Note that wire-wrapped epidural catheters must be removed prior to MRI.
10. Patients receiving high dose steroids and/or morbid obesity at increased risk for epidural lipomatosis and reduced spinal canal compliance.
Nerve Blocks

• Distal peripheral NB
  – A single- or multiple-injection NB
  – E.g., Femoral NB, II-IH nerve block, TAP

• Proximal (deep) NB
  – Plexus & paravertebral NB

• Neuraxial NB
  – Spinal & epidural segmental
Epidemiology of Neuraxial & PNB after 1981  
*Flandin-Blety*  
1995; Giaufre 1996; Ecoffey 2010; Polaner 2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Design (surveys)</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>Retrospective</td>
<td>Adverse effects (reversible) 0.5%</td>
</tr>
<tr>
<td></td>
<td>Epidural</td>
<td>5 severe neuro-deficit &amp; death 0.02%</td>
</tr>
<tr>
<td>1996</td>
<td>Prospective</td>
<td>Overall transient complications 0.09%, all in central blocks &amp; higher in infants</td>
</tr>
<tr>
<td></td>
<td>Central &gt; PNB</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Prospective</td>
<td>Overall reversible complications 0.12% [ 95% CI 0.09-0.17] significantly 6 times higher for central blocks &amp; children less than 3yrs</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td></td>
</tr>
<tr>
<td></td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNB 66%</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Prospective</td>
<td>95% were performed under GA</td>
</tr>
<tr>
<td></td>
<td>Caudal 40%</td>
<td>No deaths or complications lasting &gt; 3 months</td>
</tr>
<tr>
<td></td>
<td>PNB (U&amp;LE) 35%</td>
<td>AE/complications ~European surveys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High incidence with catheters and &lt; 6 months</td>
</tr>
</tbody>
</table>
Epidemiology and morbidity of regional anesthesia in children: a follow-up one-year prospective survey of the French-Language Society of Paediatric Anaesthesiologists (ADARPEF)

<table>
<thead>
<tr>
<th>Age</th>
<th>n</th>
<th>NB type</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mo. – 13 yrs (10)</td>
<td>10</td>
<td>Caudal, lumbar &amp; thoracic epidural</td>
<td>Total spinal one patient No PDPH</td>
</tr>
<tr>
<td>Ex-PT 1 &amp; 3 mo.</td>
<td>2</td>
<td>Spinal</td>
<td>High spinal</td>
</tr>
<tr>
<td>9 yrs</td>
<td>1</td>
<td>Axillary</td>
<td>Convulsion</td>
</tr>
<tr>
<td>1.5mo-17 yrs</td>
<td>15</td>
<td></td>
<td>Cardiac toxicity (2 tachycardia &amp; 13 bradycardia)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Axillary</td>
<td>Ropivacaine in 5 patients</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Caudal</td>
<td>Bupivacaine in 10 patients</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>DPNB+II-IH</td>
<td>Test dose in 6 patients</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Lumbar epidural</td>
<td>Drug error in one caudal NB with 0.75%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Thoracic epidural</td>
<td>No one required active treatment</td>
</tr>
</tbody>
</table>

Pediatric Anesthesia 2010
Epidemiology and morbidity of regional anesthesia in children: a follow-up one-year prospective survey of the French-Language Society of Paediatric Anaesthesiologists (ADARPEF)

<table>
<thead>
<tr>
<th>Age</th>
<th>n</th>
<th>NB Types</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mo. &amp; 3 yrs</td>
<td>2</td>
<td>II-IH</td>
<td>Colonic puncture. Treated with Antibiotics</td>
</tr>
<tr>
<td>8-13 yrs</td>
<td>5</td>
<td>Epidural -Thoracic -Caudal -Lumbar Femoral NB</td>
<td>Nerve irritation/injury Horner’s syndrome 18 h after d/c of epidural Hypoesthesia/paresthesia 48h Unilateral paresthesia for 3 weeks LBP required analgesia for 11 mo. Popliteal nerve deficit 48h after d/c of block</td>
</tr>
<tr>
<td>2-12 yrs</td>
<td>4</td>
<td>Lumbar epidural II-IH Femoral NB Paravertebral</td>
<td>Local infection Wrong side Catheter fracture; required removal under LA Intrapleural infusion</td>
</tr>
</tbody>
</table>

Conclusion: Incidence of complications is low and no permanent sequelae
Neurological Complications Associated with Epidural Analgesia in Children: A Report of 4 Cases of Ambiguous Etiologies

- 4 cases: 1 long-term and 3 permanent neurologic complications

Potential risk factors

- Surgical-related
  - Dorsal lithotomy particularly with Trendelenberg (elevation of CVP)

- Anesthesia-related
  - Episodic hypotension
  - Large LA volume infusion “epidural compartment syndrome”
  - Unrecognized dural puncture & neural toxicity
  - Neurotoxicity; inappropriate drug use e.g., butorphanol

- Patient-related:
  - Lipomatosis (chronic steroid therapy; obesity)

Neuraxial Analgesia in Neonates and Infants: A Review of Clinical and Preclinical Strategies for the Development of Safety and Efficacy Data

• “It is essential to undertake extensive animal testing with further evaluation of any neurotoxic effects before pediatric use.”

• “The potential for spinal drug toxicity may present a greater problem in early life because of the dynamic properties intrinsic to neuraxial development.”

• Safety unproven: ketamine, clonidine, butorphanol, midazolam, neostigmine, etc.

Appropriate Epidural Catheter Placement

Success

• Cover surgical sites
  – Derma-, myo- & osteo-tomes
  – Viscero-tomes

Safety & side-effects

• Catheter tip within the spinal segments innervating the area of maximum pain

Figure 1. Segmental epidural anesthesia and analgesia (Sethna & Suresh Pain in Neonates & Infants 2007)

Society for Pediatric Anesthesia
education • research • patient safety

Intensive Review of Pediatric Anesthesia
2015
Recommended Local Anesthetic for a Single Volume-Dose

Dalens 1995, Busoni 1986; Takasaki 1977

- Caudal epidural:  
  - T6-8: 1.0 ml/kg  
  - T8-10: 0.75 mL/kg  
  - T10-12: 0.5 ml/kg

- Lumbar epidural:  
  - 0.05 ml/kg/segment  
    - 0.5 -1 ml/kg max. 20 mL, administered incrementally to desired level

- Thoracic epidural: no data
Pharmacokinetic profiles of epidural bupivacaine and ropivacaine following single-shot and continuous epidural use in young infants

Alyson Calder¹, Graham T. Bell¹, Martin Andersson², Alison H. Thomson²,³, David G. Watson² & Neil S. Morton¹

Pediatric Anesthesia 22 (2012)

• Postoperative $\alpha_1$-acid glycoprotein & total bupivacaine and ropivacaine concentrations accumulated during infusions but not unbound drugs
  – Immature CYP 1A3 & 3A4 isoenzymes
  – Increased AAG (surgical stress)

• Maximum unbound concentrations of bupivacaine (0.12 mg/L) & ropivacaine (0.13 mg/L) below toxic thresholds (0.3 and 0.6 mg/L in adults)

• No evidence of clinical toxicity

• Recommend: bolus & infusion is safe & effective
Recommended epidural infusion doses:

- Infants 40-63 week PMA (GA+ postnatal) 
  1.5 mg/kg bolus, 2h later followed by infusion 0.2 mg/kg/h over 2-3 days
- Infants < 4 months: 0.25 mg/kg/h
- Infants > 4 months: 0.3-0.4 mg/kg/h
- Caveat: AAG rise in response to surgical stress but can be impaired in severe illness

Local Anesthetic Toxicity
(www.Lipidrescue.org)

• Caveat: There are no standard methods of intralipid therapy in adults & children
  – Based on dose or rate/kg or guided by sign and symptoms?
  – Maximum safe dose?
  – 20% Intralipid: 1.5 ml/kg over 1 min. then 0.25 ml/kg/min
ASRA 2011 Checklist for Treatment of Local Anesthetic Systemic Toxicity

- **GET HELP**
- **Airway Management; Seizure suppression** with benzodiazepines; avoid propofol; **activate CPB/ECMO capability**
- **Manage Arrhythmias**: ACLS with modifications
  - Avoid vasopressin, Ca\(^+\) channel blocker, β-blocker, local anesthetic
  - Reduce individual Epi doses to < 1mcg/kg
- **Lipid emulsion (20\%) therapy**
  - **Bolus** 1.5 ml/kg over 1 min.
  - **Continuous infusion** 0.25 ml/kg/min
  - Repeat bolus once or twice for persistent cardiovascular collapse
  - Double infusion to 0.5 ml/kg/min if hypotensive
  - **Continue infusion** for at least 10 min after cardiovascular stability
  - Recommended upper limit: ~10 ml/kg lipid emulsion over first 30 min.
- **Post events** at [www.lipidrescue.org](http://www.lipidrescue.org); report lipid use [www.lipidregistry.org](http://www.lipidregistry.org)
Spinal Anesthesia in Infants: Indications

**Indications**
- Infants less than 60 weeks postconceptional age
- Sole anesthetic: no analgesic/sedative supplementation
- Surgery below T10 level
- Surgical duration 60-80 minutes
- Performed at L3-S1 interspaces

**Advantages**
- Onset with 2-4 minutes with tetracaine
- Stable hemodynamic
- Motor block < T5 does not suppress ventilation

**Disadvantages**
- Success rate is dependent of the skill of the operator
### Spinal Anesthesia in Infants


<table>
<thead>
<tr>
<th>Local Anesthetic</th>
<th>Age</th>
<th>Mean Dose (mg/kg)</th>
<th>Mean Sensory Block</th>
<th>Mean surgical duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bupivacaine 0.5% (isobaric)</td>
<td>&lt; 5 mo.</td>
<td>0.8</td>
<td>T3</td>
<td>80</td>
</tr>
<tr>
<td>Levobupivacaine 0.5% (isobaric)</td>
<td>&lt; 55 weeks postconceptional age</td>
<td>1</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Tetracaine 0.5% (hyperbaric) with epinephrine (10-40 µg)</td>
<td>&lt; 5 mo.</td>
<td>0.4-0.8</td>
<td>T2-4</td>
<td>60-90</td>
</tr>
</tbody>
</table>
Brachial Plexus Block

• Interscalene single injection NB
  – At level of trunks or roots
  – Upper (C5-6) & middle (C7) are preferentially blocked (shoulder & lateral arm)
  – Lower trunk (C8-T1) is posterior/inferior often incompletely blocked, supplement may required
  – Frequent phrenic nerve block (C5)
Intensive Review of Pediatric Anesthesia

Chelly J 2004; Neal J 2009
Interscalene NB: Indications

*Lanz et al., 1983*

- **Shoulder surgery**
  - Shoulder joint, proximal humerus & lateral 2/3 of clavicle

- **Not suitable for forearm & hand surgery**
  - Insufficient block of the inferior trunk (ulnar n.) in 50% of patients
Interscalene Block

Ultrasound anatomy

Skin

SCM

Lateral

MS

C5

C6

C7

AS
Complications

• Inadvertent: total spinal, epidural & intra-vertebral injection
• High frequency of hemi-diaphragm paralysis
• Hematoma, systemic LA toxicity, Horner syn
• Nerve injury (in adults):
  – 60% of claims of neural injury when under GA
  – In children no data: BEWARE!!
Interscalene NB: Contraindication

• Relative contraindication
  – Chronic obstructive airway disease
  – Contralateral paralysis of phrenic or recurrent laryngeal nerves
  – Ipsilateral preexisting neurologic deficit
• Phrenic nerve paralysis occurs in 50% of patients without respiratory difficulty in healthy patients
Supra- & infra-clavicular NB
Indications & contraindications

• Supra-clavicular: arm, forearm and hand
  – More reliable NB for radial and ulnar nerves

• Infra-clavicular & axillary NB:
  – elbow, forearm & hand
  – Infraclavicular is more reliable in anesthetizing axillary and musculocutaneous nerves than axillary NB

• Contraindications for supra- & infra-clavicular NB
  – Bilateral supraclavicular NB: risk of respiratory compromise due to potential pneumothorax (6%) and/or phrenic nerve (50%) block
  – Delayed pneumothorax can present with first 12h
Supraclavicular Nerve Block

Pleura is easy to see...

Lateral

Res MB

Rib

Pleura

Pleura
Infra-clavicular NB: Coracoid approach

- Indication is same as axillary NB: elbow, forearm, & hand

- Advantages over axillary NB:
  - No special upper extremity positioning is necessary (no abduction necessary)
  - Includes musculocutaneous & intercostal brachial nerves which are just outside the sheath
  - Bilateral NB is safe; does not involve phrenic nerve
  - Ideal for long-term continuous catheter technique
Infraclavicular N B
Orebaugh & Bigeleisen 2007
Axillary Single Injection NB

• Disadvantages
  – In adults the block is incomplete
  – Axillary and musculocutaneous nerves are out of sheath
  – LA diffusion is incomplete due to septal barriers
  – Success rate > 90% with multiple injections

• In infants & toddler is usually complete
  – No prospective trials
Axillary NB

Axilla - Median, Ulnar, Radial, and MC Nerve
Sensory & motor nerve block Assessment

Chelly 2004
Lower Extremity NB

• Indications: depends on surgical sites

• Hip surgery
  – Ilio-femoral approach (femoral & obturator n.)
  – Anterolateral approach: (both lumbar & sacral plexus)
  – Postero-lateral approach (both lumbar & sacral plexus)
Lower Extremity NB

• Lower extremity surgical sites
  – Thigh: Femoral n.
  – Anterior knee: Femoral n.
  – Posterior knee: Sciatic n.
  – Lower leg: Sciatic nerve (+/- saphenous for medial site)
  – Foot sciatic nerve (+/- saphenous for medial site)
  – Tourniquet (thigh, calf)

• Nerve stimulator (aim at 0.5mA, 2 Hz, 0.1 ms)
  – A useful guide
  – Use an insulated needle 25-22 gauge; 50-100 mm
Lumbar Plexus NB: L1-5 [T12 overlap]
Sacral Plexus NB: S1-4 [L5 overlap]

- Femoral & obturator n. (L2-4) supply anteromedial hip capsule
- Sacral plexus (S1-4)
  - Superior gluteal n. (L4-S2)
  - Sciatic n. (S1-4)
    - Supply posterior hip
- Combination for THA & TKA
Classic Lumbar Plexus Block

- 1-2 cm lateral to transverse process, LOR
- Confirmation: quadriceps contraction
- 0.5mL/kg volume with 1:400,00 epi
- Medial needle orientation‡ adductor m. contractions or vastus medialis‡ complications
- Monitor PR & BP for intravascular, epidural/intrathecal injection

Tuffier’s line

Intensive Review of Pediatric Anesthesia
2015
Lumbar Plexus Ultrasound Guidance
### Table 14-3

**Success Rate of Lumbar Plexus Block with Various Neural Localization Techniques**

<table>
<thead>
<tr>
<th>Reference</th>
<th>N</th>
<th>Technique</th>
<th>Sensory Block</th>
<th>Motor Block</th>
<th>Number of failures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fem</td>
<td>Lateral Femoral Cutaneous</td>
<td>OBT</td>
</tr>
<tr>
<td>Parkinson et al., 1989 (26)</td>
<td>27</td>
<td>Psoas at L3, NS</td>
<td>95%</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>Psoas at L4–L5</td>
<td>95%</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Femoral, paresthesia</td>
<td>85%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Femoral, NS</td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Seeberger et al., 1995 (42)</td>
<td>39</td>
<td>Femoral, NS 20 mL</td>
<td>41%</td>
<td></td>
<td>92%</td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>Femoral, NS 40 mL</td>
<td>44%</td>
<td></td>
<td>93%</td>
</tr>
<tr>
<td>Lang et al., 1993 (40)</td>
<td>32</td>
<td>Femoral, Paresthesia 30 mL</td>
<td>96%</td>
<td></td>
<td>81%</td>
</tr>
<tr>
<td>Farny et al., 1994 (7)</td>
<td>45</td>
<td>Psoas, NS 1.0–0.5 mA</td>
<td>100%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Morau et al., 2003 (78)</td>
<td>20</td>
<td>Femoral, NS at 0.5 mA bolus via catheter</td>
<td>100%</td>
<td></td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Fascia iliaca bolus via catheter</td>
<td>86%</td>
<td></td>
<td>92%</td>
</tr>
<tr>
<td>Tokat et al., 2002 (76)</td>
<td>30</td>
<td>Psoas, NS</td>
<td>100%</td>
<td></td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>Femoral, NS</td>
<td>93%</td>
<td></td>
<td>63%</td>
</tr>
<tr>
<td>Pandin et al., 1998 (96)</td>
<td>132</td>
<td>Psoas, NS at 0.3 mA bolus via catheter</td>
<td>100%</td>
<td></td>
<td>93%</td>
</tr>
<tr>
<td>Capdevila et al., 1998 (79)</td>
<td>50</td>
<td>Femoral, NS at 0.5 mA 30 mL</td>
<td>90%</td>
<td></td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Fascia iliaca, 30 mL</td>
<td>90%</td>
<td></td>
<td>38%</td>
</tr>
<tr>
<td>Kaloul et al., 2004 (77)</td>
<td>20</td>
<td>Femoral, NS at 0.5 mA bolus via catheter</td>
<td>88%</td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Psoas, NS at 0.5 mA bolus via catheter</td>
<td></td>
<td></td>
<td>90%</td>
</tr>
</tbody>
</table>

_1Use of uninsulated needles, no mA given._

_2These studies reported rate of success for blocking the components of the lumbar plexus using a variety of nerve localization techniques and approaches to the nerves. Fem, femoral; LFC, lateral femoral cutaneous; OBT, obturator; NS, nerve stimulator. From Enneking FK, Chan V, Greger J, et al. Lower extremity peripheral nerve blocks: Essentials of our current understanding. Reg Anesth Pain Med 2005;30:4–35, with permission._

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**Society for Pediatric Anesthesia**

education • research • patient safety

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2015
Femoral NB (L2-4)

Chelly 2004; Enneking et al., 2009

Anterior skin

Quadriceps muscles

Femur & anterior knee joint

Lumbar Plexus
- Femoral N.
- Saphenous N.
- Obturator N.
- Lat.Fem.Cut. N.

Thigh tourniquet: LFCN & obturator NB

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Femoral NB: Landmarks

Neal 2009; Karmakar & Kwok 2013

Dose: 0.3-0.5 mL/kg, Max 25 mL
LFCN Block

- SC infiltration just medial to ASIS, 1-2 cm below inguinal ligament
- Fanwise infiltration 5-10 mL maximum
Fascia Iliaca Compartment NB

• Double “pop” technique
• Advantages
  – No neurovascular injury
  – No need for nerve stimulator
  – 3-in-1 nerve block
    • Volume same as FNB
    • 90% success rate

• Disadvantage
  – Duration shorter than FNB
  – Continuous infusion
Fascia Iliaca Compartment vs. Classic 3-in-1 Block *Dalens et al.*
*Anesth Analg* 1989

<table>
<thead>
<tr>
<th>Sensory block</th>
<th>FIC*</th>
<th>3-in-1*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral n.</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Motor</td>
<td>02%</td>
<td>08%*</td>
</tr>
<tr>
<td>LFCN</td>
<td>92%</td>
<td>15%*</td>
</tr>
<tr>
<td>Obturator n.</td>
<td>88%</td>
<td>13%*</td>
</tr>
<tr>
<td>Genitofemoral n.</td>
<td>92%</td>
<td>17%*</td>
</tr>
<tr>
<td>Adequate analgesia</td>
<td>90%</td>
<td>20%</td>
</tr>
<tr>
<td>Complications</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Analgesic duration</td>
<td>5 h</td>
<td>6 h*</td>
</tr>
</tbody>
</table>

* n = 60, ages 0.7 - 17yr
Sciatic NB: Indications

- Approach depends on ability of the patient to assume certain position; supine, lateral or prone
- Complete anesthesia/analgesia of the foot and ankle, except for saphenous strip
- Combination with lumbar plexus block provides complete unilateral lower extremity nerve block
Sciatic NB: Posterior approach of Labat
Neal J. 2009; Karmakar & Kwok 2013

- Lateral position
- Landmarks not always easily identified
- Anterior approach associated with possible vascular puncture, hip joint entry
Sciatic NB: Subgluteal lateral approach

Karmakar & Kwok 2013

• Confirmation
  – Foot dorsi-flexion/eversion [common peroneal n.]
  – Foot plantar flexion/inversion [tibial n.]

• High success rate: 83% blockade of posterior cutaneous n. of the thigh (thigh tourniquet, knee surgery)
Subgluteal Lithotomy Approach

- Easy to perform
- Mid-point of a line between greater trochanter & ischial tuberosity
- Nerve stimulator [or US]
- Success rate 90-95% [incomplete tibial or peroneal n.; in separate fascial planes]
  - Volume may improve diffusion

GT = Greater trochanter
IT = Ischial tuberosity
Saphenous NB: Paravenous technique
Enneking et al., 2009

• Useful for tourniquet below the knee
• A SC paravenous (on either side of the vein) injection of a total 3-5 mL of a LA
• 100% success rate
Popliteal Nerve Block: Lateral approach

- Supine
- Stable indwelling catheter
- Surgical anesthesia of the foot & ankle
- Combined with saphenous or femoral NB provides complete anesthesia of the distal leg and foot
- Nerve stimulator or US guidance
- Popliteal fossa block is associated with potential intravascular injection
Transversus Abdominis Plan (TAP) Block

Karmakar & Kwok 201

- Posterior TAP at mid-axillary line
- Subcostal TAP is at mid-clav line
- T10: Rectus sheath block
- TAP space is between internal oblique and transversus abdominis muscles
- Dose 0.2 mL/kg/ side
- Indications: Unilateral/ bilateral Orchiopexy, herniotomy, appendectomy, laparoscopic,
- Cx: Visceral perforation

Thoracolumbar T7 - L1 innervates ant abd wall sensory & motor nerves
Segmental blocks
Recommended Local Anesthetic
for a Single Volume-Dose

*Dalens 1995*

- Brachial plexus NB: 1 mL/kg maximum 20 mL
- Axillary NB: 0.5 mL/kg
- Lumbar plexus NB: 1 mL/kg
- Proximal NB
  - Femoral, sciatic: 0.2 mL/kg (> 50 kg max. 10 mL)
  - Forearm nerves: 0.15 mL/kg (> 50 kg max. 7.5 mL)
- Distal NB: 0.1 - 0.2 mL/kg; lower dose for distal nerves
- FIC nerve block: 1 mL/kg
### Selection of US probes

*Griffin & Nicolls 2010*

<table>
<thead>
<tr>
<th>Probe</th>
<th>Crystal Array</th>
<th>Frequency</th>
<th>Field depth</th>
<th>Resolution</th>
<th>Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Linear</td>
<td>6–13 MHz</td>
<td>1.8–6 cm</td>
<td>0.5 mm axial</td>
<td>Brachial plexus, abdominal wall, femoral and distal sciatic, peripheral nerves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 mm lateral</td>
<td></td>
</tr>
<tr>
<td>Curvilinear</td>
<td>Curved face</td>
<td>2–5 MHz</td>
<td>5–16 cm</td>
<td>2 mm axial</td>
<td>Neuraxial, lumbar plexus and proximal sciatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 mm lateral</td>
<td></td>
</tr>
</tbody>
</table>

- **High frequency transducer**
  - Decreased tissue penetration and better resolution
  - Useful for superficial structure visualization e.g., interscalene brachial plexus
- **Low frequency transducer**
  - Better tissue penetration and decreased resolution
  - Useful for deep structure visualization e.g., sciatic nerve
Relative Echogenicity of Tissues
Karmarkar & Kwok 2013

Isoechoic
- Similar echoic
- Poor differentiation

Hyperechoic
- Most nerves
- Muscles
- Fascia, aponeuroses, pleura, peritoneum

Hypoechoic
- Some nerve hyperechoic with rim
- Fat lobule - compressible
- Arteries – round, pulsatile, non-comp
- Veins – oval, non-pulsatile, comp
- Color Doppler - artery v. vein

Anechoic
- Bone with hyperechoic edge

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Axis of scanning transverse and longitudinal planes

Tsui & Suresh 2010

The needle shaft is seen as a “dot” along its trajectory

The needle shaft is seen as a “linear” structure with tip
Nerve stimulator vs. Ultrasound
Choyce RAPM 2001; Urmey Anesthesiol 2002; Koff Anesthesiol 2008

- Motor responses varies 0.5 to 1-3 mA; risk of nerve injury (sedated)
- In children; no data

- Specificity: Needle shaft passing obliquely through in-plane view: any point along the shaft looks like the needle tip
- US is more sensitive indicator of needle tip than either paresthesia or nerve stimulator
Ultrasound Safety

The Needle tip should be in view at all times

*Macaire et al., 2008*

- Needle approaching a nerve
- Local anesthetic spread around a nerve “halo or donut sign”
- Intraneural injection “intraneural cyst”
USG RNB

• Nerve stimulator does not eliminate the risk of nerve damage
• US might minimize the nerve damage but this claim remains to be tested
• US allows for lower doses of local anesthetics
## TABLE 1. Statements of Evidence and Grades of Recommendation for the Outcomes Evaluated in This Review

<table>
<thead>
<tr>
<th>Evaluated Outcomes</th>
<th>Statements of Evidence</th>
<th>Grade of Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peripheral nerve blockade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduces block performance time</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>No evidence found.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hastens block onset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound guidance reduces onset of sensory block for upper extremity PNBs.</td>
<td>Ib</td>
<td>B</td>
</tr>
<tr>
<td>Improves block success</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound guidance does not improve block success rates in upper extremity PNBs when compared with nerve stimulation guidance.</td>
<td>Ib</td>
<td>B</td>
</tr>
<tr>
<td>Ultrasound guidance improves the intraoperative block success for PNBs at the trunk.</td>
<td>Ib</td>
<td>A</td>
</tr>
<tr>
<td>Improves block quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound guidance prolongs analgesia for upper and lower extremity blocks.</td>
<td>Ib</td>
<td>A</td>
</tr>
<tr>
<td>Ultrasound-guided blocks at the anterior trunk improve early postoperative pain relief for inguinal and umbilical procedures.</td>
<td>Ib</td>
<td>B</td>
</tr>
<tr>
<td>Reduces local anesthetic dose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound guidance reduces the volume of local anesthetic required for successful perioperative analgesia in PNBs.</td>
<td>Ib</td>
<td>A</td>
</tr>
<tr>
<td>Ultrasound guidance achieves sufficient intraoperative analgesia using minimal volumes (0.1 mL/kg) of local anesthetic for blocks of the nerves in the anterior trunk.</td>
<td>Ib</td>
<td>B</td>
</tr>
</tbody>
</table>

Ib = case series; B = no body of literature; A = recommended
TABLE 1. Statements of Evidence and Grades of Recommendation for the Outcomes Evaluated in This Review

<table>
<thead>
<tr>
<th>Evaluated Outcomes</th>
<th>Statements of Evidence</th>
<th>Grade of Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuraxial anesthesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear visibility of landmarks</td>
<td>Ib</td>
<td>A</td>
</tr>
<tr>
<td>Ultrasound enables sufficient visibility of the dura mater and ligamentum flavum in neonates, infants and children.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good prediction of depth to LOR</td>
<td>III</td>
<td>B</td>
</tr>
<tr>
<td>Preprocedural ultrasound imaging offers a moderate prediction of the depth to LOR.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visibility of needle puncture or LOR</td>
<td>III</td>
<td>B</td>
</tr>
<tr>
<td>Ultrasound offers visibility of a needle within the epidural space in neonates.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visibility of catheter (directly or indirectly)</td>
<td>III</td>
<td>B</td>
</tr>
<tr>
<td>Ultrasound guidance can directly detect catheters during advancement in some young infants.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound guidance can confirm epidural catheter placement via surrogacy during injection of fluid.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduces bone contact</td>
<td>Ib</td>
<td>B</td>
</tr>
<tr>
<td>Bone contact can be reduced in most cases in infants and children using real-time ultrasound guidance.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

III = case controlled series
Conclusions

• Overall central NB and PNB in infants and children are safe in perioperative period

• Most complications can be avoided by
  – Careful patient selection
  – Appropriate technique and LA dose
  – US-guided blockade shows promise towards increased safety and reducing the dose of the LA
  – Risk reduced but not eliminated
Keep children comfortable...

...and have fun!