Neurologic Complications Associated with Regional Anesthesia

Balancing Risk with Reward

James R. Hebl, M.D.
Professor of Anesthesiology
Vice-Chair, Clinical Practice
Mayo Clinic
Rochester, Minnesota
Disclosures

• No financial relationships to disclose

• Will not be referencing off-label usages(s) of pharmaceuticals or instrumentation within this presentation
• Discuss the incidence of neurologic complications associated with regional anesthesia
• Understand the risk factors associated with perioperative nerve injury
• Describe the diagnostic evaluation and management of postoperative neurologic deficits
Neurologic Complications

Historical Perspective

- Harold Neuhof, M.D.
- Mount Sinai School of Medicine
- “…muscular spiral nerve paralysis…”
- Brachial plexus anesthesia
- “…unrelated to the (patient’s) original injury…”

Neuhof, JAMA 1914
Neurologic Complications

Historical Perspective

• Literature review (1959)
• Several cases
• "...persistent neurologic symptoms..."
• Brachial plexus anesthesia
• Injury rates: 0.1% to 5.6%
• **Etiology:** Mechanical trauma or LA toxicity

Woolley and Vandam, Ann Surg 1959
Lecture Outline

• Incidence of Neurologic Complications

• Etiology of Perioperative Nerve Injury

• Review of the Clinical Literature
  • Patient risk factors
  • Surgical risk factors
  • Anesthetic risk factors

• Double Crush Phenomenon

• ASRA Guidelines & Recommendations
Incidence of Neurologic Complications

A Review of the Clinical Literature
Incidence of Neurologic Complications

- Prospective randomized studies
- Anesthesia literature
- 2000 – 2010
- Variable neurologic complication rates

Reported Frequency

0.02%  11%

+500-fold Difference
Comparing Clinical Studies

*Apples vs. Oranges?*

- Sample sizes
- Surgical procedures and anesthetic techniques
- Providers performing blocks
- Patient status during block placement
- Exclusion criteria
- Definition of Perioperative nerve injury
- Method of postoperative evaluation
- Time of follow-up
Perioperative Nerve Injury

University of Michigan

• Retrospective investigation
• 380,690 surgical patients
• 10-year period of time
• Neurologic complication rate: 0.03% (1:3300)
  • Surgical causes of PNI excluded

• Risk Factors *
  • General or epidural anesthesia (Not SAB, PNB, or MAC)
  • Neuro, Cardiac, General, Ortho
  • PMH: Hypertension, Tobacco, Diabetes

* P < 0.05

Welch, Anesthesiology 2009
Perioperative Nerve Injury

Mayo Clinic

- Retrospective cohort study (20-year)
- 12,329 patients
- Total knee arthroplasty
- Neurologic complication rate: 0.79% (1:125)
  - Surgical causes of PNI included

Risk Factors *
- Age: O.R. 0.68 (per decade)
- Bilateral procedures: O.R. 2.51
- Tourniquet time: O.R. 1.28 (per 30-min)

* P < 0.05

Jacob, Anesthesiology 2011
Perioperative Nerve Injury

Mayo Clinic

- PNI was *not associated* with type of anesthesia
  - GA vs. Neuraxial (Spinal or Epidural)

- PNI was *not associated* with peripheral nerve blockade

Jacob, Anesthesiology 2011
Rates of PNI vs. PNB

Perioperative Nerve Injury

Peripheral Nerve Blockade

'88-'92        '93-'97        '98-'02        '03-07

Jacob, Anesthesiology 2011
Perioperative Nerve Injury

Mayo Clinic

- PNI was not associated with type of anesthesia
  - GA vs. Neuraxial (Spinal or Epidural)

- PNI was not associated with peripheral nerve blockade
  - Patients with PNI + PNB = Complete recovery less likely

Jacob, Anesthesiology 2011
**Table 3. Characteristics and Clinical Course of Perioperative Nerve Injury**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unilateral Primary (n = 56) No. (%)</th>
<th>Unilateral Revision (n = 10) No. (%)</th>
<th>Bilateral (n = 31) No. (%)</th>
<th>Overall (n = 97) No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of peripheral nerve blockade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>35 (62)</td>
<td>9 (90)</td>
<td>28 (91)</td>
<td>72 (75)</td>
</tr>
<tr>
<td>Femoral block only*</td>
<td>6 (11)</td>
<td>0</td>
<td>2 (6)</td>
<td>8 (8)</td>
</tr>
<tr>
<td>Femoral and sciatic block†</td>
<td>14 (25)</td>
<td>1 (10)</td>
<td>1 (3)</td>
<td>16 (16)</td>
</tr>
<tr>
<td>Psoas compartment and sciatic block‡</td>
<td>1 (2)</td>
<td>0</td>
<td>0</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Type of nerve injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory</td>
<td>15 (27)</td>
<td>5 (50)</td>
<td>4 (13)</td>
<td>24 (25)</td>
</tr>
<tr>
<td>Sensorimotor</td>
<td>41 (73)</td>
<td>5 (50)</td>
<td>27 (87)</td>
<td>73 (75)</td>
</tr>
<tr>
<td>Neurologic deficit documented prior to hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discharge</td>
<td>No</td>
<td>16 (29)</td>
<td>5 (50)</td>
<td>5 (16)</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>40 (71)</td>
<td>5 (50)</td>
<td>26 (84)</td>
</tr>
<tr>
<td>Neurology consultation obtained</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>40 (71)</td>
<td>8 (80)</td>
<td>18 (58)</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>16 (29)</td>
<td>2 (20)</td>
<td>13 (42)</td>
</tr>
<tr>
<td>Electromyography obtained</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>35 (62)</td>
<td>7 (70)</td>
<td>15 (48)</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>21 (38)</td>
<td>3 (30)</td>
<td>16 (52)</td>
</tr>
<tr>
<td>Degree of neurologic recovery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>0</td>
<td>1 (10)</td>
<td>1 (3)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>20 (36)</td>
<td>2 (20)</td>
<td>13 (42)</td>
</tr>
<tr>
<td></td>
<td>Complete</td>
<td>36 (64)</td>
<td>7 (70)</td>
<td>17 (55)</td>
</tr>
</tbody>
</table>

**Complete Neurologic Recovery:**

62% (All) vs. 44% (PNB)*

*P = 0.03
Serious Complications Related to Regional Anesthesia

- Prospective Survey in France

- Regional Anesthetics: 103,730
  - Neuraxial 71,053 (68%)
  - Peripheral blockade 21,278 (21%)
  - IV regional anesthesia 11,229 (11%)

- Complications:
  - Cardiac arrest
  - Death
  - Neurologic injury
  - Seizure

Auroy, Anesthesiology 1997
Cardiac Arrest       Death               Seizure         Nerve Injury

Number of Patients (N)

93 Complications (0.09%)

1:1,100

SAB
EPID
PNB

Auroy, Anesthesiology 1997
Neurologic Complications: 34 (37%)

Neuraxial anesthesia: 0.04% (1:2500)

PNB injury: 0.02% (1:5000)
Major Complications of Regional Anesthesia

- Similar Prospective Survey
- Conducted over 10 months
- 487 Anesthesiologists
- SOS Telephone Hotline (24 hr)
- Regional Anesthetics: 158,083
  - Neuraxial: 78,104
  - Peripheral nerve blockade: 50,223
  - IV regional anesthesia: 4,448
  - Peribulbar blocks: 17,071
- Major Complications

Auroy, Anesthesiology 2002
Major Complications of Regional Anesthesia

- **Peripheral Nerve Blocks:**
  - Interscalene: 3,459
  - Supraclavicular: 1,899
  - Axillary: 11,024
  - Mid-Humeral: 7,402
  - Lumbar Plexus: 394
  - Femoral: 10,309
  - Sciatic: 8,507
  - Popliteal: 952

Auroy, Anesthesiology 2002
<table>
<thead>
<tr>
<th>Technique</th>
<th>Cardiac Arrest</th>
<th>Resp Failure</th>
<th>Death</th>
<th>Seizure</th>
<th>Neuro Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISB  (N=3,459)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>SCB  (N=1,899)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Axillary  (N=11,024)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mid-Hum  (N=7,402)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lumbar Plex  (N=394)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Femoral  (N=10,309)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Sciatic  (N=8,507)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Popliteal  (N=952)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong> (N=50,223)</td>
<td><strong>1</strong></td>
<td><strong>2</strong></td>
<td><strong>1</strong></td>
<td><strong>6</strong></td>
<td><strong>12</strong></td>
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<tr>
<td>Technique</td>
<td>Cardiac Arrest</td>
<td>Resp Failure</td>
<td>Death</td>
<td>Seizure</td>
<td>Neuro Injury</td>
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<tr>
<td>Axillary (N=11,024)</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Mid-Hum (N=7,402)</td>
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<tr>
<td>Lumbar Plex (N=394)</td>
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<tr>
<td>Femoral (N=10,309)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sciatic (N=8,507)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Popliteal (N=952)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total (N=50,223)</strong></td>
<td><strong>1:3,300</strong></td>
<td><strong>5 of 12 (42%)</strong> resolved within 6 months</td>
<td><strong>12</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Risk Factors Associated with Neurologic Injury
Perioperative Nerve Injury

Contributing Factors

1. Patient Risk Factors

2. Surgical Risk Factors

3. Anesthetic Risk Factors
Patient Risk Factors and Neurologic Complications
Patient Risk Factors

- Pre-existing neurologic deficits
Pre-Existing Neurologic Deficits

Multiple Sclerosis

- Case series
- N = 3 patients
- Pre-existing "disseminated (multiple) sclerosis" undergoing spinal anesthesia
- New onset or progressive neurologic deficits
- "...spinal anesthesia may be a precipitating agent in the evolution of disseminated (multiple) sclerosis..."
<table>
<thead>
<tr>
<th>Author</th>
<th>N</th>
<th>Pre-Existing Condition</th>
<th>Anesthesia</th>
<th>Comment</th>
</tr>
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<tbody>
<tr>
<td>Critchley</td>
<td>3</td>
<td>Disseminating (multiple) sclerosis</td>
<td>Spinal</td>
<td>New or progressive neurologic deficits</td>
</tr>
<tr>
<td>Royal Soc Med</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1937</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Hammes</td>
<td>8</td>
<td>Multiple sclerosis, paresis, myelitis,</td>
<td>Spinal</td>
<td>New or progressive neurologic deficits</td>
</tr>
<tr>
<td>Minn Med</td>
<td></td>
<td>arachnoiditis</td>
<td></td>
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<tr>
<td>1943</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keschner</td>
<td>1</td>
<td>Multiple sclerosis</td>
<td>Spinal</td>
<td>Exacerbation of symptoms</td>
</tr>
<tr>
<td>J Nerve Ment Ds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stenuit</td>
<td>19</td>
<td>Multiple sclerosis</td>
<td>Spinal</td>
<td>2 of 19 (11%) Exacerbation of symptoms</td>
</tr>
<tr>
<td>Acta Neurol Belg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bamford</td>
<td>9</td>
<td>Multiple sclerosis</td>
<td>Spinal</td>
<td>Exacerbation rate 11% (vs. 4.3% with GA)</td>
</tr>
<tr>
<td>Can J Neurol Sci</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Prospective investigation

N = 254

Followed: Duration of pregnancy to 1-year postpartum

Rate of relapse (3-month intervals)
  - 1-year prior to pregnancy
  - Pregnancy trimesters (1\textsuperscript{st} / 2\textsuperscript{nd} / 3\textsuperscript{rd})
  - 1-year postpartum

Anesthetic “risk factors” – epidural analgesia
Multiple Sclerosis Relapse Rates

- Pre-Pregnancy: 0.7
- 1st Trimester: 0.2 *
- 2nd Trimester: 0.2 *
- 3rd Trimester: 0.2 *
- 0-3 Months Postpartum: 1.2 *
- 4-6 Months Postpartum: 1.2 *
- 7-9 Months Postpartum: 1.2 *

* P<0.001 vs. Pre-
• Relapse Rates
  • Lower during the 3rd trimester of pregnancy
  • Higher during the first 3-months postpartum

• Immune-shift
  • Pregnancy: Humoral immunity
  • Post-partum: Cell-mediated immunity

• Epidural analgesia (N=42) did not affect the risk of relapse
  • Epidural: 1.6 / woman / year
  • No epidural: 1.2 / woman / year
65 year-old male with Multiple Sclerosis

**US-guided ISB + GETA** for Total Shoulder Arthroplasty

Uneventful block placement with good imaging

**POD 0:** Dense sensorimotor block with burning pain

**MRI:** Brachial neuritis (Rx: Methylprednisolone)

**POD 11:** EMG confirmed Brachial plexopathy

8 mo. Postop: Persistent sensorimotor deficits
Multiple Sclerosis

Peripheral Nervous System Involvement

- Axonal demyelinating sensory and peripheral motor lesions
- Sensory abnormalities > Motor abnormalities
  
Pogorzelski, Neurol Neurochir Pol 2004

- Nerve conduction abnormalities in 14.7% of peripheral nerves in MS patients (2.4% general population)
  
Sarova-Pinhas, Acta Neurol Scand 1995

- Associated demyelinating peripheral neuropathy in MS patients
  
Hughes, British Med Journal 2002
Pre-Existing Neuraxial Disease

Risk of Surgical Anesthesia

- Retrospective investigation
- N = 139
- CNS diagnosis
- Neuraxial anesthesia or analgesia

Hebl, Anesth Analg 2006
<table>
<thead>
<tr>
<th>Neurologic diagnosis</th>
<th>Number of patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-polio myelitis</td>
<td>79</td>
<td>56.4%</td>
</tr>
<tr>
<td>Multiple sclerosis</td>
<td>35</td>
<td>25%</td>
</tr>
<tr>
<td>Traumatic spinal cord injury</td>
<td>13</td>
<td>9.3%</td>
</tr>
<tr>
<td>Amyotrophic lateral sclerosis</td>
<td>5</td>
<td>3.6%</td>
</tr>
<tr>
<td>Guillain-Barré syndrome</td>
<td>3</td>
<td>2.1%</td>
</tr>
<tr>
<td>Meningomyelocele</td>
<td>2</td>
<td>1.5%</td>
</tr>
<tr>
<td>Cauda equina syndrome</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>Huntington’s chorea</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>Neurosyphilis with paraplegia</td>
<td>1</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

* One patient had a diagnosis of both multiple sclerosis and prior poliomyelitis.
Pre-Existing Neuraxial Disease

Risk of Surgical Anesthesia

- Retrospective investigation
- N = 139
- CNS diagnosis
- Neuraxial anesthesia or analgesia
- Block success: 98%
- New or worsening neurologic complications
  - 0 of 139 (0%, 95% C.I. = 0.0% to 0.3%)

“...Neuraxial anesthesia or analgesia should not be considered a contraindication...”

Hebl, Anesth Analg 2006
Pre-Existing Spinal Stenosis or Lumbar Disk Disease

- Narrowing of the spinal canal
  - Thickened posterior vertebral elements
  - Facet joints
  - Ligamentum flavum
  - Osteophytes
  - Herniated discs

- Chronic underlying neural compromise

- Clinicians reluctant to perform neuraxial anesthesia
  1. Increased risk of neurologic injury
  2. Increased risk of block failure (maldistribution)

Katz, NEJM 2008
Neurologic Complications

Neuraxial Anesthesia & Analgesia

- National Epidemiologic Survey (10-yr)
- Serious neurologic complications of neuraxial anesthesia
- Swedish Anesthesia Departments (N=72)

Regional techniques
- Spinal: 1,260,000
- Epidural: 450,000

Complications: 127 (0.007%) 67% permanent

Moen, Anesthesiology 2004
• **Neuraxial Technique**
  - Epidural > Spinal (5x↑ complications)

• **Hematoma (after Epidural)**
  - OB: 1:200,000
  - Ortho: 1:3,600 (Female + TKA)
  - Thromboprophylaxis (appropriate): 33%
  - Pre-existing spine pathology: 25%

• **Cauda equina**
  - Spinal stenosis or LA toxicity: 28% of complications (36 of 127)
  - Permanent neurologic injury: 100%
  - Known spinal stenosis (preoperatively): 7%
  - Spinal stenosis > Orthopedic patients

“...In the presence of spinal stenosis, CNB should be performed only after careful consideration – particularly epidural blockade; 3x higher risk...”
Pre-Existing Spinal Stenosis or Lumbar Disc Disease

- Retrospective investigation
- $N = 937$ patients
- Spinal stenosis or lumbar disc disease
Table 1. Neurologic History of Patients with Spinal Stenosis or Lumbar Disk Disease

<table>
<thead>
<tr>
<th>Neurologic feature</th>
<th>Number of patients (N = 937)</th>
<th>Percentage (%)&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurologic diagnosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal stenosis</td>
<td>187</td>
<td>20</td>
</tr>
<tr>
<td>Compressive radiculopathy</td>
<td>530</td>
<td>57</td>
</tr>
<tr>
<td>Disk herniation (without radiculopathy)</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>Peripheral neuropathy</td>
<td>210</td>
<td>22</td>
</tr>
<tr>
<td>Multiple (&gt;1) diagnoses</td>
<td>180</td>
<td>19</td>
</tr>
<tr>
<td>Neurologic history</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor deficits</td>
<td>479</td>
<td>51</td>
</tr>
<tr>
<td>Sensory deficits</td>
<td>568</td>
<td>61</td>
</tr>
<tr>
<td>Pain/dysesthesias</td>
<td>882</td>
<td>94</td>
</tr>
<tr>
<td>Hyperreflexia</td>
<td>74</td>
<td>8</td>
</tr>
<tr>
<td>History of prior spinal surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>s/p Laminectomy</td>
<td>193</td>
<td>21</td>
</tr>
<tr>
<td>s/p Diskecctomy</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>s/p Spinal fusion or other</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Disease status at time of block placement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute exacerbation (&lt;30 days)</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>Subacute exacerbation (1–6 months)</td>
<td>69</td>
<td>8</td>
</tr>
<tr>
<td>Chronic/stable (&gt;6 months)</td>
<td>828</td>
<td>89</td>
</tr>
<tr>
<td>Unknown</td>
<td>8</td>
<td>—</td>
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<td>Disease progression within last 12 months</td>
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<td>Active symptoms at time of neuraxial block</td>
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<tr>
<td>Unknown</td>
<td>279</td>
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</table>

<sup>a</sup> Percentages based upon those patients with available data.
Block Site Relative to Pathology

- Precisely at the Level: 24%
- 1-2 Levels: 52%
- 3-4 Levels: 21%
- >4 Levels: 3%

Hebl, Anesth Analg 2010
Pre-Existing Spinal Stenosis or Lumbar Disc Disease

• Neuraxial blockade
  • Spinal  58%
  • Epidural  38%
  • Continuous SAB  3%
  • CSE  1%

• Neurologic complications
  • N = 10  (1.1%, 95% C.I. = 0.5% to 2.0%)
  • Surgical etiology in 4 (40%) cases
  • Anesthetic complication rate: 0.6%

Hebl, Anesth Analg 2010
Pre-Existing Spinal Stenosis or Lumbar Disc Disease

- Neuraxial blockade
  - Spinal 58%
  - Epidural 38%
  - Continuous SAB 3%
  - CSE 1%

- Neurologic complications
  - N = 10 (1.1%, 95% C.I. = 0.5% to 2.0%)

“...Spinal canal pathology (multiple diagnoses) significantly increases the risk of neurologic complications after neuraxial blockade...”

Hebl, Anesth Analg 2010
Pre-Existing Spinal Stenosis or Lumbar Disc Disease

- Prior Spine Surgery (N = 207)
  - s/p Laminectomy n=193 (21%)
  - s/p Diskectomy n=9 (1%)
  - s/p Spinal fusion n=1 (0.5%)

- Outcomes
  - *No differences* in successful outcome: 97% vs. 98%
  - *No differences* in technical complications: 12% vs. 11%
  - *No differences* in neurologic complications: 1% vs. 1.4%

Hebl, Anesth Analg 2010
Regional Anesthesia after Spine Surgery

- 33 patients s/p laminectomy undergoing tetracaine spinal
  - 100% success
  - No neurologic complications
  Berkowitz, Anesth Analg 1980

- 18 patients s/p Harrington rod placement undergoing labor epidurals
  - 95% success
  - 52% required repeated boluses of LA or had a patchy block
  Daley, Reg Anesth 1990

- 5 patients s/p spinal fusion undergoing labor epidurals
  - 80% success
  - 20% complicated placement; Heme after 3 attempts; Successful SAB
  Hubbert, Anesth Analg 1985
Regional Anesthesia after Spine Surgery

- 42 patients s/p discectomy undergoing epidural labor analgesia
- Similar bupivacaine requirements vs. Controls
- No difference in time-to-placement
- No comment on neurologic complications

Bauchat, Anesth Analg 2012
Preexisting Deficits Due to Peripheral Disease Processes
Chemotherapy-Induced Peripheral Neuropathy

• Serious dose-limiting side effect

• Chemotherapeutic agents:
  • Platinum-based
  • Taxanes
  • Vinca alkaloids
  • Thalidomide
  • Bortezomib
  • Ixabepilone

• Incidence: 30-40% (Range: 0-70%)

• Symptoms: Sensory paresthesias and pain (stocking-glove)

• Onset: Weeks-to-months after initiation

• Duration: Partially reversible, commonly permanent

Pachman, Clin Pharm Ther 2011
Chemotherapy-Induced Peripheral Neuropathy

- 14-year old female
- Osteogenic sarcoma (humerus)
- 15-week chemotherapy
  - Cisplatin 840 mg/m²
- Postoperative ISB (PNS)
- Severe brachial plexopathy
- EMG: Diffuse axonal loss distal to nerve trunks
- Persistent sensorimotor deficits after 18 months

Hebl, Anesth Analg 2001
Chemotherapy-Induced Peripheral Neuropathy

Cisplatin Chemotherapy

- Dose-dependent neuropathy
- Occurs after doses of $\geq 300$ mg/m$^2$
- Incidence: 85%
- Deposition of platinum within the dorsal root ganglion
- Irreversible in 30% to 50% of patients – even years after therapy

Hebl, Anesth Analg 2001
<table>
<thead>
<tr>
<th>Chemotherapeutic agents</th>
<th>Cardiovascular agents</th>
<th>Antibiotics</th>
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FDA Drug Safety Communication: FDA requires label changes to warn of risk for possibly permanent nerve damage from antibacterial fluoroquinolone drugs taken by mouth or by injection

Safety Announcement

[8-15-2013] The U.S. Food and Drug Administration (FDA) has required the drug labels and Medication Guides for all fluoroquinolone antibacterial drugs be updated to better describe the serious side effect of peripheral neuropathy. This serious nerve damage potentially caused by fluoroquinolones (see Table for a list) may occur soon after these drugs are taken and may be permanent.

- FDA Warning: Peripheral neuropathy
- Fluoroquinolone use (oral or I.V.):
  
  “...serious or disabling nerve damage...[that]...may be permanent...”

- Increased cases within Adverse Event Reporting System (AERS)
- Risk unrelated to duration of treatment or age of the patient

FDA Drug Safety Alert, August 15, 2013
Perioperative Nerve Injury

**Patient Risk Factors**

- Pre-existing neurologic deficits
- Diabetes mellitus
Diabetic Polyneuropathy

**Clinical Characteristics**

- Most common cause of neuropathy worldwide
- Initial presentation: 4% - 8%
- Chronic disease: 15% - 50%
- Likelihood increases with duration of disease
- Progression associated with glycemic control
- Clinical forms:
  - Rapidly reversible
  - Symmetrical Polyneuropathy
  - Mononeuropathy (CN III and IV)
  - Truncal
  - Plexopathy
Diabetic Polyneuropathy

Proposed Etiologies

1. Metabolic: Polyol Pathway
   - Accumulation of sorbitol within nerves as excess glucose is converted to sorbitol
   - Incidence & severity decreased with tight control

2. Ischemic: Evidence of microvascular angiopathy

3. Glycosylation: Glycosylated end-products deposited in and around nerves

Williams, Reg Anesth Pain Med 2009
Diabetic Polyneuropathy

Animal Studies

Summary

• Motor conduction blockade more profound in diabetic animals exposed to local anesthetics

• Neural edema and fiber injury significantly greater in diabetic animals (intermediate- and long-acting LA)

1. Diabetic patients may require less local anesthetic to produce anesthesia

2. Reduction in dose may be necessary to prevent nerve injury by doses normally considered safe
Diabetes Mellitus

Spinal Anesthesia

- Prospective investigation
- N = 88 patients
- Categorized
  - Diabetic (n=44)
  - Non-Diabetic (n=44)
- CSF Analysis + Spinal anesthesia (Bupivacaine 0.5%)
- Results (Diabetic patients)
  - Onset time (Maximal block level): Faster
  - Duration (Maximal block level): Longer
  - Time of Block regression: Slower

Echevarria, Eur J Anaesth 2008
Diabetes Mellitus

Spinal Anesthesia

- CSF Concentration (mg/dL)
  - Glucose
  - Total Protein
  - IgG

Diabetics
Non-Diabetics

- CSF Osmolarity
- CSF volume (lumbar)

† Plasma [Glucose]

* P<0.0001

Echevarria, Eur J Anaesth 2008
- N=567 patients with preexisting peripheral neuropathy
  - Peripheral sensorimotor neuropathy (52%)
  - Diabetic polyneuropathy (48%)
- Neuraxial anesthesia or analgesia (SAB > Epidural > CSE)
- Technical complications: 11.5%
  - Paresthesia > Heme > Dural puncture
- New or Progressive Neurologic Deficits: 2 (0.4%)
  - 95% CI = 0.1% to 1.3%
- **Risk:** 10-fold higher than general population
Diabetes Mellitus

Block Success

- Retrospective investigation
- N = 1858 patients
- Categorized
  - Diabetic (n=262)
  - Non-Diabetic (n=1596)
- Supraclavicular blockade (landmark-based paresthesia)

Results
- Diabetic patients have significantly higher block success rate (96% vs. 87%; P<0.001)
- Success independent of BMI

Gebhard, Reg Anesth Pain Med 2009
Comparison of Subgluteal Sciatic Block Duration in Type II Diabetic vs. Non-Diabetic Patients

- Diabetic patients: Evidence of Peripheral Neuropathy (Monofilament)
- Onset time: No difference
- Duration of sensory block: Increased (21 hr vs. 17 hr; P<0.01)
- Duration of motor block: Increased (16 hr vs. 12 hr; P<0.01)

Relationship Between Glycosylated Hemoglobin Level and Popliteal Sciatic Nerve Block Performance in Diabetic Patients

- HgbA1c: (I) 5%-6% (II) 7%-8% (III) >9%
- Block performance time (PNS): Longer Group III
- Regression time sensorimotor block: Longer Group III
- Glycemic control impacts block characteristics
Perioperative Nerve Injury

Patient Risk Factors

- Pre-existing neurologic deficits
- Diabetes mellitus
- Age and Gender
  - **Upper extremity:** Male + older
  - **Lower extremity:** Female + younger
- Extremes of body habitus
- Preoperative valgus deformity or knee contracture
- Tobacco use

Urban, Reg Anesth 1994  
Horlocker, Anesth Analg 1994  
Warner, Anesthesiology 1999  
Horlocker, Anesth Analg 2006  
Hebl, Anesth Analg 2006  
Welch, Anesthesiology 2009  
Jacob, Anesthesiology 2011
Ulnar Neuropathy & Male Gender
Role of Anatomy
Surgical Risk Factors and Neurologic Complications
Perioperative Nerve Injury

Surgical Risk Factors

• Surgical trauma or stretch
• Tourniquet ischemia
• Surgical bleeding
• Perioperative inflammation

Neal, Reg Anesth Pain Med 2002
Lynch, J Elbow Shoulder Surg 1996
Horlocker, Anesth Analg 1994
Warner, Anesthesiology 2000
Jacob, Anesthesiology 2011
Post-surgical inflammatory neuropathy

Nathan P. Staff,¹ JaNean Engelstad,¹ Christopher J. Klein,¹ Kimberly K. Amrami,² Robert J. Spinner,³ Peter J. Dyck,¹ Mark A. Warner,⁴ Mary E. Warner⁴ and P. James B. Dyck¹

- N = 33 patients (Age: 17-83 yrs)
- Surgical procedures (ortho, abdominal, thoracic, dental)
- Multifocal (42%), focal (36%), or diffuse (22%) neuropathy
- Onset: <24 hr to 3 weeks
- Presentation: acute pain and weakness
- Commonly not within the “spatio-temporal” span of surgery or regional anesthetic

Brain 2010; 133:2866-80
Post-surgical inflammatory neuropathy

Nathan P. Staff,¹ JaNean Engelstad,¹ Christopher J. Klein,¹ Kimberly K. Amrami,² Robert J. Spinner,³ Peter J. Dyck,¹ Mark A. Warner,⁴ Mary E. Warner⁴ and P. James B. Dyck¹

- **EMG:** Axonal damage
- **MRI:** Abnormal increased T2 nerve signal
- **Nerve biopsy:** Epineural lymphocytic inflammation and evidence of microvasculitis (+/- signs of ischemic injury)
- **Treatment:** High-dose methylprednisolone
- **Prognosis:** Significant improvement over (extended) time
- **Risk Factors:** Preexisting neuropathy or inflammation, transfusion, volatile anesthetics, diabetes, infection, tobacco use

*Brain* 2010; 133:2866-80
Perioperative Nerve Injury

Surgical Risk Factors

- Surgical trauma or stretch
- Tourniquet ischemia
- Surgical bleeding
- Perioperative inflammation
- Vascular compromise
- Postoperative edema
- Infection or abscess
- Cast compression
- Patient positioning

Neal, Reg Anesth Pain Med 2002
Lynch, J Elbow Shoulder Surg 1996
Horlocker, Anesth Analg 1994
Warner, Anesthesiology 2000
Jacob, Anesthesiology 2011
Horlocker, Anesth Analg 2006
Staff, Brain 2010
The Risk of Persistent Paresthesia is Not Increased with Repeated Axillary Block

- 607 patients undergoing 1,614 AXB
- Neurologic complication: 8.4% (All causes)
- Etiology: Anesthesia (11%) vs. Surgical (89%)
- Direct trauma (73%), inflammation/infection (11%), hematoma (7%), cast (5%), tourniquet ischemia (4%)

Horlocker, Anesth Analg 1999

Preliminary Results of the Australasian Regional Anaesthesia Collaboration

- 6,950 patients undergoing 8,189 PNB
- Ultrasound-guidance: 63%
- Neurologic complication: 0.5% (Overall)
- Etiology: Anesthesia (10%) vs. Other (90%)
- Deficit >12 month: 33%

Barrington, Reg Anesth Pain Med 2009
Anesthetic Risk Factors and Neurologic Complications
Perioperative Nerve Injury

Anesthetic Risk Factors

• Mechanical trauma
  • Needle or catheter
  • Intrafascicular injection

• Chemical injury
  • Local anesthetic neurotoxicity

• Ischemic injury
  • Epinephrine
  • Perineural edema
Neurologic Complications and Nerve Localization

Transarterial vs. Paresthesia vs. PNS vs. Ultrasound

- Transarterial vs. single paresthesia vs. PNS (Axillary)
  - No differences in neurologic complications (N=59; 0%)

- Mechanical paresthesia vs. PNS (Interscalene)
  - No differences in postoperative neurologic symptoms (N=218; 10%)

- PNS vs. Ultrasound-guidance (Interscalene)
  - No differences in postoperative neurologic symptoms (N=219; 10%)

Goldberg, Anesthesiology 1987
Liguori, Anesth Analg 2006
Liu, Anesth Analg 2009
Neurologic Complications and Nerve Localization

Nerve Injury and Ultrasound-guidance

- Severe brachial plexopathy after US-guided ISB  
  Koff, Anesthesiology 2008

- Flaccid paralysis after intraneural injection during US-guided ISB  
  Cohen, Reg Anesth Pain Med 2010

- Severe brachial plexopathy after US-guided SCB  
  Reiss, Reg Anesth Pain Med 2010

- Neurologic complications: 8.2% (1,010 US-guided nerve blocks)

- Block etiology: 33% (deficit >6 mo)  
  Fredrickson, Anaesthesia 2009
Regional Anesthesia and Perioperative Nerve Injury

The “Double-Crush” Phenomenon
"Double-Crush Phenomenon"

**Primary insult (Patient Risk Factors)**
- Mechanical compression (Entrapment)
- Ischemic (Microangiopathy)
- Toxic (Chemotherapy)
- Metabolic (Diabetes mellitus)

**Secondary insult (Surgical & Anesthetic Factors)**
- Surgical stretch / trauma
- Postoperative hematoma
- Compressive dressing
- Mechanical trauma
- Toxic
- Ischemic
Axoplasmic flow

- Normal
- Single insult
- Denervation
- Double Crush
- Denervation
Diagnostic Evaluation and Management of Perioperative Nerve Injuries
Diagnostic Evaluation

5 Steps to Assess

1. Confirmation of neural dysfunction

2. Historical features
   - Onset
   - Sensory, motor, pain
   - Continuous vs. fluctuating vs. progressive
   - Preoperative deficits
Diagnostic Evaluation

5 Steps to Assess

1. Confirmation of neural dysfunction
2. Historical features
3. Physical exam
   - Neurologic exam
   - Bleeding or hematoma
   - Infection or abscess
Diagnostic Evaluation

5 Steps to Assess

1. Confirmation of neural dysfunction
2. Historical features
3. Physical exam
4. Imaging studies
   - Ultrasound
   - CT scan
   - MRI
Diagnostic Evaluation

5 Steps to Assess

1. Confirmation of neural dysfunction
2. Historical features
3. Physical exam
4. Imaging studies
5. Electrodiagnostic studies

- EMG: Localize pathologic site of neural dysfunction
- Nerve Conduction Studies: Assess functional integrity of nerves
  - (a) number of functioning axons (amplitude)
  - (b) state of myelin (conduction velocity)
Decline of Sensory and Motor Action Potentials after Axonal Injury

Days from Acute Axonal Injury

Percent (%) Amplitude

CMAP
SNAP
Management of Perioperative Nerve Injuries

• Critical to rule-out correctable causes
  • Hematoma, abscess, cast compression

• Vast majority: transient and self-limited neuropathies

• Conservative measures
  • Limb protection, physical therapy, ROM exercises

• Neurology Consult
  • Deficits cannot be explained by surgical or anesthesia
  • Severe deficits

• Neurosurgical Consult
  • Progressive or persistent deficits
    (3-5 months)
Summary

- PNI are rare and devastating complications of surgery (and RA)

- Risk Factors for Nerve Injury
  - Patient
  - Surgical
  - Anesthetic

- Carefully evaluate patient and surgical risk(s) preoperatively

- Risk may vary based upon type and severity of disease and anesthetic technique

- Carefully assess risk vs. benefit, provide full disclosure, and document appropriately