Nerve Repair: How to Avoid Complications

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Avoiding Pitfalls

- Proper Diagnosis
- Treatment Decisions
- Nerve Preparation
- Nerve Repair Strategies
- Post-Operative Management

Preoperative Considerations

- Patient expectations
  - Patient characteristics
  - Injury characteristics
  - 50-80% good/functional recovery
    - M3/S3 or better
Preoperative Considerations
Discuss treatment options
- Repair/reconstruct/transfer
- Graft options

Office Evaluation
Sensorimotor deficits that correlate with laceration injury
- Proceed with exploration

Global Injury Assessment
Wound assessment
- Contamination
- Soft tissue defects
Associated injuries
- Tendons
- Vascular
- Fractures
Requirements for Success

1. Healthy proximal and distal nerve stumps *MOST IMPORTANT*
2. Proper alignment of proximal and distal stumps
3. Potential Nerve Gap Management
4. Tension-free neurorraphy (repair)
5. Atraumatic and secure coaptation

Timing of Surgery

Gunshot wounds and open fractures
- Treat like closed injuries
- Explore if part of surgical treatment of other injury

Timing of Surgery

High-energy injuries
- May initially underestimate the zone of injury
- Tag nerve ends
- Wait ~3 weeks for definitive treatment
Intraoperative Considerations

Patient positioning
- Stable access to site
Microscope available

Instruments

- Specialized microsurgical instruments
  - Preferably at least 10 cm long
  - Fine spring loaded needle holders and scissors
- Surgical loupes
  - (see wealthy relative or win lotto)
- Operative microscope
  - (at least 20X)

Dissection

- Fibrous flexor sheath
- Digital n.
Healthy Nerve Stumps

This is the MOST important step

- Appreciate the zone of injury
- Need to remove damaged tissue both proximally and distally
- Do resection BEFORE determining final repair technique

Resection Matters

- Suturing Scarred Nerve Provides Limited Value
- Scar Inhibits Revascularization, Axonal Regeneration and Schwann Cell Migration
- Proximal Stump should have at least 75% preserved neural elements (Wolff et al., 2013)

Nerve Debridement

- Morphologic features of healthy nerve ends:
  - Normal fascicular architecture
  - Pliability / tactile feel of nerve
  - Appearance of “pouting” fascicles
  - Punctate endoneurial bleeding
- Tourniquet?
How much do I trim?

Dr. Buncke Gregory

Respect the Coaptation
Tension may compromise the nerve repair and lead to ischemia within the nerve

Tension Matters
However, “Bunching” may prevent the new fascicles from regenerating properly
**Proper Alignment**

Assess fascicular alignment
- Align fascicular patterns
- Align epineural vessels

**Perform epineural repair**
- Consider group fascicular repair
  - Sutured at inner epineurium
    - Radial nerve at elbow
    - Median and ulnar nerves at wrist

**Nerve Repair**

- **Fascicular repair**
  - Most common indications for grouped fascicular repair
    - Median nerve in distal third of forearm
    - Ulnar nerve in distal third of forearm
    - Sciatic nerve in thigh
The Coaptation

Assessing tension
- Epineural sutures with 9-0 nylon
- Nerve ends “kissing” / “just touching”
- No gapping with extremity ROM

Tension-Free Neurorraphy

Assessing tension

Neutral posture of adjacent joints limits:
- Joint contractures
- Pain from tension during rehab
- Failure of repair

Nerve transposition/Mobilization?
- Not much gain, increased devascularization
Atraumatic and Secure Coaptation

- Appropriate number of sutures
- Conduit/connecter-assisted
- Fibrin glue
  - Decreases gapping
  - Does not improve strength

References:

Tension Causes Restriction in the Blood Supply

- Tension at the repair site:
  - 8% stretch impedes venous return
  - 16% stretch causes arterial ischemia

- At minimal elongation, there is slight scarring but blood vessels are not constricted.

- With increased elongation, first signs of tissue injury are observed along with ~50% reduction in blood flow.

- Excessive elongation can cause complete blockage of blood vessels.

References:

If attempt to repair gap creates tension → primary repair results in suboptimal outcome

Increased tension showed impaired axonal growth in a preclinical model.2
What About the Gap

• Conduits

  - Autologous Vein Graft Entubulation
  - Commercially available Hollow Tube Conduits
    - Integra Lifesciences: NeuraGen™ and NeuraWrap™ (bovine collagen)
    - Synovis – Neurotube® (PGA)
    - Polyganics – Neurolac® (poly-ester)
    - AxoGuard Nerve Connector/Protector (porcine submucosa)

• Processed Nerve Allografts

  - Avance® Nerve Graft

• Autologous Nerve Grafts (Autograft)

Role of Tube Conduits

• Tubes play an important role in modern nerve repair

• Consideration should be given to:
  - The function of the nerve
    - Typically reserved for non-critical sensory nerves
  - The length of the gap
    - Less than 20mm
  - The diameter of the nerve
    - The larger the diameter, the shorter the gap should be
    - Less than 6 mm in mixed nerves
  - Resurgence as an aid to direct repair with very short gap (<5mm)
Connector Assisted Coaptation: Providing Alignment and Avoiding Tension at the Coaptation

Entubulation of the Coaptation

No forced mismatch from overly tight repair

Barrier to Axonal Escape, Scarring and Inflammatory Infiltration

Entubulation of the Coaptation

Conduits– as Coaptation Aids

• Place nerve ends in and suture to epineurium
• Allow a very small gap (less than 5mm) between the face of the nerve ends to ensure no misalignment.
• Reduces tension and fibrosis of the sutures
• Allows the regenerating nerve fibers to find the optimum path

Entubulation Technique Summary

Trim to healthy nerve
Measure Nerve
Horizontal Mattress Suture Technique
Suture Second Side
Flush with Saline
Completed Nerve Repair

Flush with Saline
Suture Second Side
Flush with Saline
Completed Nerve Repair
Increasing Gap Length

Fibrin cable is robust enough to allow regeneration at short gaps.

Thinning restricts the regenerative space at longer gaps.

The cable does not form when length limits are exceeded. This can result in no regeneration or a neuroma.

Decreasing Efficacy

The cable does not form when length limits are exceeded. This can result in no regeneration or a neuroma.

References:
Whitlock et al., 2009 Muscle and Nerve

Length Limitations of Conduits

Tube Assisted Coaptation Clinical Outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Nerve Injury Types</th>
<th>Test Article</th>
<th>Gap</th>
<th>Outcomes*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lundborg 1998</td>
<td>Mixed</td>
<td>Silicone Coaptation Aid vs. Suture</td>
<td>&lt;5mm</td>
<td>Comparable to Suture, better sensation</td>
</tr>
<tr>
<td>Weber et al., 2000</td>
<td>Sensory</td>
<td>PGA Coaptation Aid vs. Suture</td>
<td>&lt;5mm</td>
<td>91% Coaptation Aid, 49% Suture</td>
</tr>
<tr>
<td>Farole et al. 2009</td>
<td>Sensory</td>
<td>Wrapping vs. Non-Wrapping</td>
<td>&lt;2mm</td>
<td>Pain with Wrapping</td>
</tr>
<tr>
<td>Buektaynas et al. 2013</td>
<td>Sensory</td>
<td>Collagen Coaptation Aid vs. Suture</td>
<td>&lt;6mm</td>
<td>Comparable to Suture at 2 years</td>
</tr>
</tbody>
</table>

Conduits Limitations

• Length
  • Impacts reliability of Outcomes

• Diameter
  • Proper size match is essential >1mm larger decrease efficacy
    • Isaacs et al JRS 2014, Moore et al. Hand 2010

• Response to Materials
  • Extrusion
  • Encapsulation/Scar
Limitations to Gap size?

Reports from Published Literature:
- Lundborg et al. (199?)
  - 5mm gap
  - Silicone conduit equivalent to direct repair
- Weber et al. (2000)
  - ≤5mm 100% recovered Static 2PD
  - >5mm 66% recovered Static 2PD
- Battiston et al. (2005)
  - Only 4/19 good/excellent results
  - 3/4 for 3-4cm gaps poor
- Lohmeyer et al. (2009)
  - Greater than 15mm no recovery

Future of Tube Conduits

- ECM Components
- Internal Architecture
- Lumenal Fillers
- Neurotrophic Factors
- Neurotropic Factors
- Cell Delivery
- Electro-conductive

Bellamkonda et al., Biomaterials 2011

Tension-Free Neurorrhaphy

Deleterious effects of tension
- Ischemia, Fibrosis

Limitations of nerve stretch:
- 8% causes transient ischemia
- 10% may be acceptable in pliable nerves
- 15% leads to irreversible ischemia

Bareis 2000, Sivjan 2000, Kricun
Nerve Repairs

- Direct muscular neurotization
  - Insert proximal nerve stump into affected muscle belly
  - Results in less than normal function but is indicated in certain cases

- Epineural Repair
  - Primary repair of the epineurium in a tension free fashion
  - First resect proximal neuroma and distal glioma
  - It is critical to properly align nerve ends during repair to maximize potential of recovery

Nerve Repairs

- Nerve grafting
  - Autologous graft
  - Remains the gold standard of repair for segmental defects > 5cm is autologous nerve grafting
  - Digital nerve defects
    - Wrist to common digital nerve bifurcation
      - Use sural nerve
    - MCP to DIP level
      - Use LABC, AIN, PIN or MABC
  - Collagen conduit
    - Defects up to 1.5 cm
    - Quality of nerve recovery drops with gaps >5mm
  - Allograft
    - Off-the-shelf option for defects up to 7cm

What do I use?

- 9-0 nylon for digital nerve repairs
- 8-0 nylon for median and ulnar nerve repair (wrist and above)
- 8-0 nylon for synthetic nerve conduits
Postoperative Care

Splint extremity for soft tissue rest

Benefit of tension-free neurorraphy:
• Begin hand therapy according to associated injuries
  • Flexor tendons
  • Fractures
• Isolated nerve injuries
  • Initiate ROM 5-10 days following repair
  • Initiate ROM 2-3 weeks following nerve transfers

Summary Successful nerve repair will depend:
- Patient Age
- Type of Nerve Injures
- Mechanism of Injury
- Extent of concomitant injuries affecting tissue bed
- Location of injury
- Degree of injury
- Patient Comorbidities
  - Touching back to healthy nerve tissue
  - Alignment of nerve ends
  - Leave a small gap (<5 mm)
  - Between nerve ends
  - Tension free coaptations
  - Barriers to control ingrowth and Axonal Escape
  - Wrap vs. Connector vs. Allograft vs. Autograft

Case Example

42YO o/w healthy RDM male
- Numbness L thumb and index
- Thumb weakness
- Minimal/no pain
- Irritating, does not interfere w/ ADL
History

- Started 1 ½ years ago
  - Diagnosed w/ CTS (w/ NCS)
  - Endoscopic CTR
    - Uneventful according to op report
  - Immed. post op:
    - Patient reports worsening pain/numbness and inability to abduct thumb
      - Surgeon’s notes: sens intact to LT and motor fx normal
    - Sees patient regularly for 9 months
      - Inconsistent exam, symptoms improving
      - Subjective complaints noted

History continued

- Undergoes 3 separate NCS and ultrasound
  - Increased latency and decreased amplitude
  - EMG c/w denervation of APB
  - U/S: c/w nerve constriction one cm distal to crease
- Patient told to “exercise” thumb
- After 9 months scheduled for revision CTR
  - Case postponed when surgeon in car accident

Exam

- Thenar atrophy
- Inability to abduct thumb
- No sharp/dull discrimination thumb, index, radial half of middle finger
- Strong but non-focal Tinel’s over carpal tunnel
Now what?

- More exercises?
- More time?
- More studies?
- Live with it?
- Surgery?
Repair options?

- Conduit?
- Autograft?
- Allograft?
Case 2

- 71 yo taken to the OR emergently by trauma service for accidental self inflicted shot gun blast to left medial brachium (+ETOH)
  - Emergent vein grafting to brachial artery
  - Hand team (not me) identified median nerve which was intact
  - Ulnar nerve not explored
• Sent to me 3 mos out with no median or ulnar nerve function
  – Supported by NCS/EMG
• Now what?
  – Wait it out?
  – Nerve transfers?
  – Tendon transfers?
  – Explore
    • How to repair?

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Surgical exploration

• 4 mos post injury
• Nerves intact
  – Median N. feels fibrotic... Multiple areas of “neuroma-in-continuity”
  – Ulnar nerve not as bad... But not normal
• Now what?
  – Intra-operative nerve studies did not reveal any regenerating axons

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Median N... 7-8 cm defect
Shot gun pellets found in both nerves

Ulnar N... 5.5cm defect
4 cable sural nerve graft 8cm long

5.5 cm 4-5mm diam allograft

Fibrin glue added... since we had it out already
Nerve Injury Classification & Intervention Timing

Grabb & Smith's Plastic Surgery, 2007