Nerve Transfers in the Upper Extremity

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Learning Objectives
1. Define nerve transfers (NT)
2. Describe the rationale and indications for NT
3. List the principles of NT
4. Understand NT nomenclature
5. Better understand commonly performed NT and their outcomes

Nerve transfers are important techniques in the surgeon's armamentarium for brachial plexus and complex nerve reconstruction.

History

• Balance (1903) SAN - facial nerve
• Tuttle (1913) SAN & cervical plexus
• Vulpian (1920) transfer of MPN
• Seddon (1963) transfer of ICN
• Narakas popularization NT four decades ago

Definition

• Sacrifice function of a (lesser valued) donor muscle to restore function in recipient nerve and its muscle(s)

Indications

• NTs most commonly used for reconstruction of brachial plexus and complex peripheral nerve injuries

Indications

• Proximal nerve end is nonfunctional
• Delayed presentation
• Nerve reconstruction would require a very long nerve graft that would exceed expected viability of motor end plates (>18 months)
• Zone of injury unclear or broad with dense scarring
Contraindications

- Superior reconstructive option exists
- Excessive time between injury & reinnervation (>18 months)
- Donor nerve motor strength < M4

Principles of Motor NT

1. Expendable donor nerve
2. Pure motor donor nerve
3. Good number of donor nerve motor fibers
4. Donor nerve muscle M5
5. Good size match with recipient

Principles of Motor NT

6. Reinnevrete recipient nerve close to target muscle
7. Direct nerve repair
8. Use similarly behaving neuromuscular units (agonistic donor and recipient nerve)
   - Important role of cortical plasticity for functional recovery

Nomenclature

1. Intraplexal vs. Extraplexal Transfers
2. Distal Transfers
3. Single vs. Dual Transfers
4. Direct Nerve Transfers
5. Motor vs. Sensory Transfers
6. End-to-end, end-to-side, reverse end-to-side Transfers

Intraplexal vs. Extraplexal

**Intraplexal**
- Donor nerve originates in BPLX
  - Ulnar nerve ➔ biceps motor branch
  - Median nerve ➔ brachialis motor branch
  - Triceps branches of radial nerve ➔ axillary nerve (AXN)

**Extraplexal**
- Donor nerve originates outside BPLX
  - SAN ➔ S5N
  - ICN or phrenic nerve ➔ MCN

Distal Transfer

- NT that are at or distal to elbow
Single vs. Dual Transfer

**Single transfer**
- Use of one NT to achieve one action
  - ulnar nerve FCU fascicle → biceps motor branch for elbow flexion

**Dual transfer**
- use of two NTs to achieve one action
  - ulnar nerve fascicle → biceps motor branch and a median nerve fascicle → brachialis motor branch for elbow flexion

Direct Nerve Transfer

- Donor nerve coapted to recipient nerve without an interposed graft

Motor vs. Sensory Transfer

- Goal of recovering motor or sensory function
- NT to restore sensory function decrease neuropathic pain

End-to-end NTs

- Direct coaptation of donor nerve to recipient nerve
- End-to-end NT best

End-to-side NTs

- Coaptation of proximal end of recipient nerve to epineural window in the side of an intact and functioning donor nerve
- End-to-side NT have demonstrated efficacy in sensory nerves

Reverse end-to-side NTs

- End of donor nerve is coapted to an epineural window in the side of an intact but functionally compromised recipient nerve
Nomenclature

- **Extraplexal**
  - SSN
  - MCN
  - C7-T1 (ipsilateral and contralateral)
  - Thoracodorsal
  - Proximal ulnar (Oberlin)
  - Proximal median (brachialis motor branch)
  - Triceps branch of radial nerve
- **Intraplexal**
  - C7 (ipsilateral and contralateral)
  - Medial pectoral nerve
  - Thoracodorsal
  - Proximal ulnar
  - Proximal median (brachialis motor branch)
  - Triceps branch of radial nerve
- **Distal Transfers**
  - Brachialis motor branch
  - Ulnar nerve motor branch
  - Supinator branches
  - Posterior interosseous nerve
  - Median nerve branches to radial nerve branches
  - Sensory branches

Common Nerve Transfers

<table>
<thead>
<tr>
<th>Nerve Transfer of Choice</th>
<th>Shoulder</th>
<th>Elbow</th>
<th>Intrinsic Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilize, abduction &amp; ext rotation</td>
<td>SAN + SSN + Radial + AxN</td>
<td>Flexion</td>
<td>Ulnar intrinsic + median</td>
</tr>
<tr>
<td>Dual NT:</td>
<td>Ulnar FCU + MCN + Median + MCN</td>
<td>Ulnar FCU + MCN</td>
<td>AIN + ulnar motor branch</td>
</tr>
<tr>
<td>ICN + ICN</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Extraplexal

Spinal Accessory Nerve ➔ Suprascapular Nerve

- SAN ➔ SSN
- dual nerve transfer to restore shoulder function
- Inferior branch of SAN divided distally and directly transferred to SSN
- Superior branches to trapezius left intact
- Preserving strong trapezius function

Outcomes

Spinal Accessory Nerve ➔ Suprascapular Nerve

- Dual NT for shoulder function lead to improved results over single transfers to AxBN
- Poor external rotation continues to affect outcomes
Intraplexal
Triceps Branch of Radial Nerve → AxN

• Branches to long, medial, or lateral head of triceps → AxN
• For external rotation, transfer to both the anterior branch and the Teres minor branch are recommended.

Single NT: Radial to AxN: Intra-op EMG

Single Transfer
Triceps Branch of Radial Nerve → AxN

Single Transfer
Triceps Branch of Radial Nerve → AxN

Dual Transfer
SAN → SSN + Radial → AxN

Dual Transfer
SAN → SSN + Radial → AxN
### Outcomes

**SAN → SSN + Radial → AxN**

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients</th>
<th>M4 Deltoid</th>
<th>Abduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leechavengvongs et al (2003)</td>
<td>7/7</td>
<td>7/7</td>
<td>2/2</td>
</tr>
<tr>
<td>Bertelli and Ghizoni (2004)</td>
<td>10/10</td>
<td>7/10</td>
<td>0/0 (average, 92°)</td>
</tr>
</tbody>
</table>

- **Leechavengvongs et al. (2003)**
  - 7/7 patients - M4 deltoid & 124° of abduction

- **Bertelli and Ghizoni (2004)**
  - 10 patients with C5-6 BPLX injury
  - 3/10 - M4 abduction
  - 7/10 - M3 abduction (average, 92°)

**Garg et al. (2011)**
- 74% of patients M4 or higher

### Intraplexal Transfers

**Ulnar Nerve Fascicle → Biceps Motor Branch**

- **Oberlin et al. (1994)**
  - 1 or 2 fascicles of ulnar nerve → biceps motor branch
  - Intra-op EMG to identify the best FCU fascicle (lateral or central part of ulnar nerve)

### Single Ulnar FCU NT - 1 year post op

- Single Ulnar FCU NT – M3 only
Ulnar Nerve Fascicle → Biceps Motor Branch

Outcomes

- 30/32 patients M4 biceps

- 32 patients with upper root BPLX
- 24/32 patients ≥M3 biceps

Intraplexal
Dual Transfer: Ulnar Nerve Fascicle → Biceps Transfer
and Median Nerve Fascicle → Brachialis

- Dual transfer to regain elbow flexion
- Transfer of ulnar nerve fascicle → biceps motor branch
- Transfer of median nerve fascicle (FCR or FDS) → brachialis motor branch

Dual Transfer: Ulnar Nerve Fascicle → Biceps Transfer
and Median Nerve Fascicle → Brachialis
Dual Transfer: Ulnar & Median to elbow: early innervation

Dual Transfer: Ulnar & Median to elbow: 1 year post-op

Outcomes

Mackinnon et al (2005)
Ray et al (2011)

- 10/10 M4 elbow flexion
- 23/29 ≥ M4 elbow flexion
- 4/29 M3 elbow flexion

Mackinnon & Liverneaux recommend dual transfer for elbow flexion
Authors concluded that, compared with traditional nerve grafting for restoration of elbow function, nerve transfers had improved outcome

Extraplexal Intercostal Nerve

- ICNs most useful and dependable extraplexal donors
- Used most frequently C5-T1 plexus lesion
- Up to 7 ICNs can be transferred
- ICNs → elbow flexion
- Other recipients include AxN, LTN, and SSN

ICN ➔ MCN

ICN ➔ MCN
Outcomes

**Merrell et al (2001)**
- 72% ≥M3 elbow flexion following direct transfer
- 47% ≥M3 when interposed nerve grafts used
- Not a synergistic transfer
- Motor learning takes dedicated patient effort and considerable time

Distal Transfers
Distal AIN ➔ Ulnar Nerve Motor Branch

- In high ulnar nerve lesions, AIN branch to PQ transferred to ulnar motor branch

AIN ➔ Ulnar Motor: Intrinsics at 1 year

AIN ➔ Ulnar Motor: Intrinsics at 1 year
Distal Transfers

**Distal AIN → Ulnar Nerve Motor Branch**

Novak and Mackinnon (2002)

- 8/8 reinnervation of intrinsics at 18 months
- Pinch (2.2 lb preop to 13.8 lb postop)
- Grip strength (8.8 lb to 61.2 lb)

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