The Hand to Shoulder Center

Principles of Tendon Transfers
TENDON TRANSFER: definition

- A tendon transfer procedure relocates the insertion of a functioning muscle-tendon unit (MTU) in order to restore lost movement and function at another site.
Indications

- **most common indication:** is a peripheral nerve injury that has no potential to improve. This includes nerve injuries that are physically irreparable such as root avulsions, nerve injuries that do not recover after direct nerve repair or grafting, or failed nerve transfers.
- When peripheral nerve injuries present so late that muscle re-innervation is impossible due to motor end-plate fibrosis.
- **Other common indications:**
  - include loss of muscle or tendon following trauma.
  - central neurologic deficits such as spinal cord injuries and cerebral palsy.
  - tendon ruptures in patients with rheumatoid arthritis.
  - rarer disorders, including poliomyelitis and leprosy.
Principles and pre-requisites of tendon transfer

- 1) supple joints prior to transfer,
- 2) soft tissue equilibrium,
- 3) donor of adequate excursion,
- 4) donor of adequate strength,
- 5) expendable donor,
- 6) straight line of pull,
- 7) synergy, and
- 8) single function per transfer.
1. Supple joints prior to transfer:

- The joint that the tendon transfer will move must have maximum passive range of motion prior to the procedure. A tendon transfer procedure will fail if the joint has become stiff. Often, aggressive therapy is required to achieve and maintain a supple joint before performing a tendon transfer procedure.

- If contracture release is necessary, it should be performed prior to the tendon transfer procedure, and should be followed by intensive therapy to maintain range of motion.

- Because immobilization is required after a tendon transfer procedure to allow healing of the tendon juncture, contracture release should not be performed at the same time.
2. Soft tissue equilibrium

- The principle of soft tissue equilibrium refers to the idea that a tendon transfer should pass through a healthy bed of tissue that is free from inflammation, edema, and scar. This is necessary to allow the tendon to glide freely and to minimize adhesions.
- Following a soft tissue injury, the surgeon must allow enough time to pass for the inflammation and edema to fully subside.
- If the planned tendon transfer must pass through an area of severely scarred tissue, the scar should be excised and replaced with a flap or an alternative transfer through a healthier bed should be considered.
3. Donor of adequate excursion

- The excursion or maximum linear movement of the transferred MTU should be adequate to achieve the desired hand movement. This means that the transferred MTU should have an excursion similar to that of the tendon which it is replacing.
- In adults, wrist flexors and extensors have approximately 33 mm of excursion. The extrinsic finger extensors have about 50 mm of excursion, and the extrinsic finger flexors have about 70 mm of excursion.
- Most of the time, a donor MTU with adequate excursion will be available for transfer. However, in some situations, none of the available donor MTUs have the required excursion. In these cases, the tenodesis effect can often be used to augment the excursion of the transferred tendon.
- For example, when a wrist flexor is transferred to restore finger extension, the excursion of the wrist flexor (33 mm) is insufficient to achieve complete finger extension (50 mm). However, if the patient flexes the wrist during finger extension, the tenodesis effect tightens the finger extensors, resulting in greater finger extension.
- *Tenodesis:
Tenodesis effect:
4. Donor of adequate strength

- the MTU to be transferred must be strong enough to achieve the desired movement, but at the same time, should not be too strong. When evaluating potential donor MTU’s, it is easiest to compare their relative strength as opposed to absolute strength.
- The flexor carpi radialis (FCR), wrist extensors, finger flexors, and pronator teres (PT) all have a relative strength of 1.
- The brachioradialis (BR) and flexor carpi ulnaris (FCU) are stronger, and have a relative strength of 2.
- Finger extensors are weaker and have a relative strength of 0.5.
- The abductor pollicis longus (APL), extensor pollicis longus (EPL), extensor pollicis brevis (EPB), and palmaris longus (PL) are all weaker still, with relative strengths of 0.1.
5. Expendable donor

- The principle of using an expendable MTU as a donor means that there must be another remaining muscle that can continue to adequately perform the transferred MTU’s original function.
- For example, the wrist has three extensors, the extensor carpi ulnaris (ECU), the extensor carpi radialis longus (ECRL), and the extensor carpi radialis brevis (ECRB). If all three are functional, one or two of the extensors can be transferred. Although wrist extension will be weakened, it will not be lost as long as there is one remaining extensor.
6. Straight line of pull

- Tendon transfer procedures are most effective if there is a straight line of pull. This is because direction changes diminish the force that the transferred MTU is able to exert on its insertion.

- A change in direction of just 40 degrees will result in a clinically significant loss of force. For example, a PT to ECRB transfer is commonly used to restore wrist extension in patients with radial nerve palsy. This transfer can be performed in an end-to-side or end-to-end fashion.

- Assuming that all other factors are equal, the end-to-end transfer will result in better function and force transfer than the end-to-side transfer, because the line of pull is straighter.

- However if a direction change is unavoidable or even necessary. In these cases, the tendon should be passed around a fixed, smooth structure that can act as a pulley.
7. Synergy

- The principle of synergy refers to the fact that certain muscle groups usually work together to perform a function or movement. Wrist flexion and finger extension are synergistic movements that often occur simultaneously during normal activity. When one flexes the wrist, the fingers automatically extend. Wrist extension and finger flexion are similarly synergistic.

- Finger flexion and extension, however, do not normally occur together and are not synergistic movements. Transferring a wrist flexor to restore finger extension adheres to the principle of synergy, whereas using a finger flexor to provide finger extension does not. A synergistic transfer is preferable, although sometimes a non-synergistic transfer is the only available option.
8. Single function per transfer

- The final principle is that a single tendon should be used to restore a single function. Transfer of one MTU to restore multiple functions will result in compromised strength and movement.
- The exception to this rule is that a single MTU can be used to restore the same movement in more than one digit. For example, the FCU cannot be used to power wrist and finger extension, or to power finger extension and thumb abduction. However, it can be used to power the extension of all four fingers.
Timing of tendon transfer

- The timing of a tendon transfer after an injury depends on the likelihood of spontaneous reinnervation and nerve recovery. If nerve repairs or nerve transfers were performed initially, then sufficient time should be allowed to determine the outcome of the initial treatment before considering tendon transfers. Keep in mind that axons regenerate at a rate of approximately 1 mm/d.

- Of note, some hand surgeons advocate early tendon transfers, particularly in patients with radial nerve palsy, even if recovery is still possible.

- In 1974, Burkhalter reported that the indications are (1) the transfer can act as a substitute during regrowth of the nerve, which will thereby reduce the time of external splinting and improve early function; (2) the transfer can act as a helper and add power to normal reinnervated muscle function; and (3) the transfer can act as a substitute when, statistically, the recovery after neurorrhaphy or nerve repair is poor.1
CONTRAINDICATIONS:

- The only absolute contraindication to tendon transfer is a lack of appropriate donors. The availability of muscle-tendon units with less than grade 5 strength is a relative contraindication. Similarly, if only muscles that have been denervated and then reinnervated are available, this is also a relative contraindication. Transfers planned in individuals with progressive neuromuscular diseases should be carefully considered before proceeding because the underlying disease process may affect the transferred unit. Lastly, satisfactory results are difficult to achieve in transfers performed to produce motion in less-than-supple joints.
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CLASSIFICATION OF NERVE INJURIES
SEDDON'S CLASSIFICATION

**Neurapraxia** — temporary paralysis of a nerve caused by lack of blood flow or by pressure on the affected nerve with no loss of structural continuity.

**Axonotmesis** —
- neural tube intact, but axons are disrupted.
- nerves are likely to recover.

**Neurotmesis** —
- the neural tube is severed.
- Injuries are likely permanent without repair.
# Classification of Nerve Injuries

(Sunderland and Seddon)

<table>
<thead>
<tr>
<th>Sunderland</th>
<th>Seddon</th>
<th>Description of Injury</th>
<th>Recovery Period</th>
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<tbody>
<tr>
<td>Mildest</td>
<td>I</td>
<td>Neuapraxia</td>
<td>≤ 3 months</td>
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<td></td>
<td>II</td>
<td>Axonotmesis</td>
<td>1 inch per month</td>
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<tr>
<td></td>
<td>III</td>
<td>During healing, excessive scarring of the endoneurium occurs that hinders axon regeneration</td>
<td>&lt; 1 inch per month where it is slowed by the scar tissue; determined by degree of scarring and involved fascicles</td>
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<tr>
<td></td>
<td>IV</td>
<td>Nerve is still in-continuity, scar builds up blocks nerve regeneration</td>
<td>Surgical intervention required to re-establish nerve transduction by removing scar tissue and reconnecting nerve segments</td>
</tr>
<tr>
<td>Most Severe</td>
<td>V</td>
<td>Neurotmesis</td>
<td>Recovery requires surgical intervention</td>
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Radial Nerve Palsy
Tendon Transfers
Radial Nerve Palsy

- Functional Deficits
  - Wrist Extension
  - Finger Extension
  - Extension And Radial Abduction Of The Thumb
Tendon Transfers
Radial Nerve Palsy

• Timing Of Tendon Transfers
  – Controversial
    • Early
      – Internal Splint At Time Of Nerve Repair
    • Conventional
      – Performed After Reinnervation Of Paralyzed Muscles Fails To Occur By 3 Months After Expected
    • Late
Tendon Transfers
Radial Nerve Palsy

• Early Transfer
  – Pronator Teres to ECRB
  – Temporary Substitute Until Reinnervation
  – Suboptimal Reinnervation – Acts To Augment Function
Tendon Transfers
Radial Nerve Palsy

- Historical Perspective
  - Evolved During The Two World Wars
  - Classic Jones Transfer (1916)
    - PT → ECRL and ECRB
    - FCU → EDC III-V
    - FCR → EIP, EDC II, and EPL
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<table>
<thead>
<tr>
<th>Tendon Transfers for Radial Nerve Palsy</th>
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<tbody>
<tr>
<td><strong>STANDARD FCU TRANSFER</strong></td>
</tr>
<tr>
<td>PT → ECRB</td>
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<tr>
<td>FCU → EDC</td>
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<tr>
<td>PL → EPL</td>
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Tendon Transfers
Radial Nerve Palsy

FCU Transfer
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Tendon Transfers
Radial Nerve Palsy

- **Incision 1:**
  - FCU And PL Transected Proximally
  - FCU Freed Up Proximally
- **Incision 2:**
  - Deep Fascia Overlying FCU Incised And Muscle Freed Proximally
  - Limit – Neurovascular Pedicle
- **Incision 3:**
  - Insertion Of PT Freed With Strip Of Periosteum
  - EPL Tendon Identified
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Tendon Transfers
Radial Nerve Palsy

• Postoperative Management
  – Splint For 4 Weeks
    • Wrist 15-30° Pronation
    • Forearm 45° Extension
    • MP Joints Slight Flexion (10-15°)
    • Thumb – Maximal Extension And Abduction
    • PIP Joints – Left Free
  – 4 To 6 Weeks
    • Removable Splint
    • Planned Exercise Program – With Therapist
Tendon Transfers
Radial Nerve Palsy

• Potential Problems
  – Excessive Radial Deviation
    – From Removing FCU
    – Further Aggravated If PT Inserted Into ECRL
    – Problem With PIN Palsy
  • Solutions
    – FCU Transfer Contraindicated With PIN Palsy
    – Reinsert ECRL Into 4th Metacarpal
  – Bowstringing Of EPL
    • Solution
      – Hook EPL Around Insertion Of APL
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Better Education, Better care, Better Outcomes